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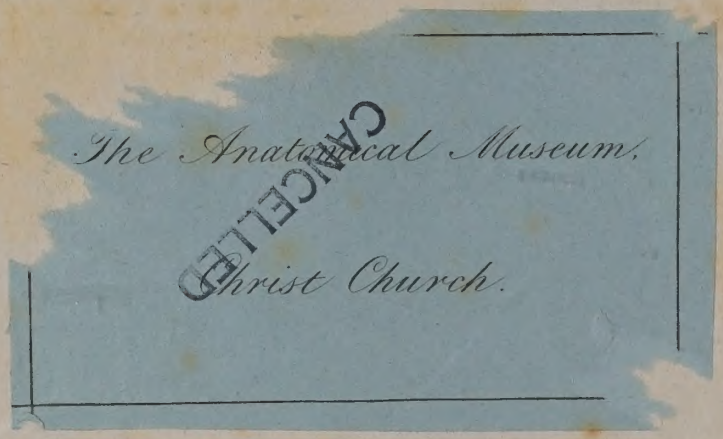

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ON

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NEW MEMOIR

ON

THE NERVOUS SYSTEM.

BY

MARSHALL HALL, M.D. F.R.S. L. & E. &c. &c.

ILLUSTRATED BY FIVE ENGRAVED PLATES.

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"WE MUST NEVER FORGET THAT IT IS PRINCIPLES, NOT PHENOMENA,—LAWS, NOT INSULATED, INDEPENDENT FACTS,—WHICH ARE THE OBJECTS OF ENQUIRY."

Preliminary Discourse on the Study of Natural Philosophy, by J. F. W. HERSCHEL, ESQ. M.A. p. 13-14.

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TO

PROF. FLOURENS,

MEMBER OF THE FRENCH ACADEMY; PERPETUAL SECRETARY OF THE INSTITUTE OF FRANCE; &c. &c.

I DEDICATE
THIS AND MY TWO FORMER MEMOIRS,
AS TO
THE PHILOSOPHER
WHO HAS, IN HIS OWN ADMIRABLE WORK,
PRESENTED US WITH
THE MOST PERFECT MODEL OF PHYSIOLOGICAL INVESTIGATION;
AND
WHO HAS, IN HIS RESPONSIBLE OFFICE,
DISPLAYED
THE MOST CANDID, IMPARTIAL, AND GENEROUS JUDGMENT
OF THE WORKS OF OTHERS.

MARSHALL HALL.

London, August, 1843.

I have again the pleasure of expressing my obligations to CHARLES SIMPSON, Esq. Surgeon, of Stamford, for the able and beautiful drawings which illustrate this volume. They are not the production of the mere artist, but of the able anatomist and physiologist.

Mr. SIMPSON has also already added some useful and *practical* observations on the subject of the following pages (see p. 84); and I expect much from the further exercise of his great talent for observation, and his just application of principles to practice.

ADVERTISEMENT.

The present Memoir may be considered as supplementary to two Memoirs, published in 1837, and as illustrative of my subsequent volume "On the Diseases and Derangements of the Nervous System," published in 1841.

I take this opportunity of correcting several misapprehensions on the part of authors of eminence in regard to my opinions.

Prof. Müller observes:—"Dr. Hall goes too far in admitting that, in the healthy state, every motion which follows true sensation is voluntary; and that all irritations of sensitive parts, which give rise to reflected motions, are unattended by sensation."

In my second Memoir, § 63, I have expressed myself thus:—"There is no *immediate** connection between sensation and motion. But there are two modes in which sensation may induce motion: the first is through *volition*; the second through *emotion*."

I have never been of opinion that reflex actions are unattended by sensation, in the perfect healthy subject, for they generally are so; but that they are not *necessarily* attended by sensation. Dr. J. Reid has particularly insisted upon the reflex action of the œsophagus, as offering an

* See Memoir I, § 25—27.

example of such action unattended by sensation, in the normal state; and the examples of reflex actions in the human subject affected by complete paraplegia, and in portions of an animal retaining only the last nodule of spinal marrow, establish the correctness of this opinion.

Prof. Müller also states, as my opinion, that muscular contraction is of *four* kinds, viz. voluntary, respiratory, involuntary, and reflected. My original view of this subject is given (in my first Memoir, p. 35, § 113—118) in the following terms:—

"The principles of the movements in the animal economy, viewed in an anatomical and functional point of light, may now be enumerated thus:

"1. The cerebrum, or the source of the voluntary motions.

"2. The medulla oblongata, or the source of the respiratory motions*.

"3. The medulla spinalis generally, the middle arc of the reflex function.

"4. The muscular fibre, or the seat of the irritability.

"5. The sympathetic, or the source of nutrition, of the secretions, &c."

I have since associated the respiratory, as identical, with the excito-motor power. (See Memoir II.)

Lastly, Prof. J. Reid, Prof. Volkmann, and others, have quoted me as saying, that the pneumogastric nerve is *insensible*. My real view is expressed in the following terms:—(See Second Memoir, p. 51, § 37).

"But as there are purely sentient nerves, it may be a question, whether there be purely excitor nerves. Such a nerve probably does not exist absolutely in health. An experiment made by Mr. Broughton, Mr. Field, and myself, in 1835, led to the conclusion that the *pneumogastric*

See Memoir II, § 126.

nerve is destitute of sentient property. This nerve is certainly the *least* sentient, and the *most* purely excitor, of any in the class *Vertebrata*."

I refer some other critics to §§ 4—25*, in the subsequent pages.

* It would be well if this re-statement of my views would induce my critics generally to distinguish, once for all, between what *is* and what *is not* claimed by me; of this, however, I may well despair. When I re-peruse the *admissions* and the *Recapitulations* in my First and Second Memoirs (see pp. 32; 30—38; 46; 112—); I am at a loss to comprehend the conduct of these gentlemen.

The very *titles* of my Memoirs point out *the* specific object of each:

My First Memoir was entitled "On the Reflex *Function* of the Medulla Oblongata and Medulla Spinalis." This important *function*, as the nervous agent in *all* the Acts of Ingestion and of Egestion in the animal œconomy, was previously unknown. It is *not* mentioned by Whytt, or Prochaska, or any other author; who, however they may cite the term reflex, or detail experiments, or treat of sympathetic actions, have not, I affirm, associated *one physiological act* with any such *reflex function* of the spinal marrow. This is, therefore, my discovery. And when I repeat that it involves the whole series of the acts of ingestion and of egestion, not one of which had been explained or understood before, I think it must be admitted to be very extensive.

My Second Memoir was entitled—"On the True Spinal Marrow, and the Excito-Motor System of Nerves." Viewed as a combined system of

1. *Incident Nerves*,
2. *Their Spinal Centre*, and
3. *Reflex Nerves*;

constituting the *Anatomy* of the whole series of the Acts of Ingestion and of Egestion; this must also be regarded as of great extent, and it is my own discovery. My claim to this discovery is admitted by the highest authority on this subject; see § 152.

Thus, then, the *Anatomy* and the *Physiology* of this extensive series of Acts were unknown. To the discovery of the anatomy and physiology of the true spinal system, therefore, I might limit my claims. But there really is, in the newly-detected modes of action of the *vis nervosa*, or excito-motor power, a discovery of equal interest; in as much as it enables us to trace the operations and uses of this power in the physiological acts of ingestion and egestion in the animal œconomy.

I cannot dismiss this advertisement without expressing my admiration of the noble candour of Prof. Müller, in his frank acknowledgment of the priority of my investigations and publications relative to the subject of these pages*.

The exclusion of sensation, of the sentient nerves, *as sentient* nerves, and of the cerebrum, as *in*-excitor, from any *essential* part in the acts of ingestion and of egestion, is also a point of great interest.

But, 1, the newly-detected modes of action of the excito-motor power; 2, the system of incident and reflex nerves with their special centre, the spinal marrow; 3, the application of these to physiology,—the physiology of all the acts of ingestion and egestion;—these may be regarded as the principal points involved in my discovery, and of these it will be difficult to find any anticipation in any author.

* See the "Handbuch der Physiologie," Ed. iii, 1838, t. i, p. 718, note; and Dr. Baly's able Translation, Ed. 2, vol. i, p. 755, note:—"The paper of Dr. Hall appeared in the second part of the Philosophical Transactions for 1833. I first stated my views in the first part of the first edition of this work, which appeared in the spring of that year, in the Chapter on the Respiratory movements, and more fully in the second part, in 1834, after Dr. Hall's paper had appeared. A paper by Dr. Hall had, however, been read at the Zoological Society on this subject in 1832; *he has, therefore, the priority.*"

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NEW MEMOIR.

ON THE

TRUE SPINAL MARROW,

AND ITS

ANATOMY, PHYSIOLOGY, PATHOLOGY, AND THERAPEUTICS.

ON THE

TRUE SPINAL MARROW,

AND ITS

ANATOMY, PHYSIOLOGY, PATHOLOGY, AND THERAPEUTICS.

---

§ I.—*Introduction.*

1. THE PRESENT Memoir will contain the additions made to our knowledge of the nervous system since the date of my last publication. It will especially set forth the connection between the nervous and sanguiferous systems, to which my attention has recently been particularly directed, both in their relations to physiology and pathology.

2. My chief attention will, however, be devoted to a further elucidation of the True Spinal System, or the system of the Acts of Ingestion and Expulsion in the animal œconomy; and in the correction of certain errors, and the removal of certain misconceptions, in regard to it, on the part of several authors. My observations have, in reality, consisted in a detail of FACTS; and I am at a loss to understand what is meant by the application to such a detail, of the term *hypothesis*. One series of *facts*, experimental in their character, establish *new Laws of action* of the *vis nervosa* of Haller (see Plate I); a second series of *facts* are physiological, and establish *the True Spinal System*, with its *Incident and Reflex Nerves*, and its application to the explanation of *the Acts of Ingestion and Expulsion* (see Plate II). These *facts* have been either well or ill observed:

if the former, the system they constitute can scarcely be termed a hypothesis; if the latter, the facts themselves should be corrected. If it be observed, that the idea, that for the distinct function of the true spinal marrow, there are distinct nerves,—a distinct order of nervous fibres,—is still hypothetical; I have only to reply, that this has always appeared to me the most *probable* view of the subject; that I have, however, never considered it as constituting any part of the true spinal system, which, I repeat, is one of *fact*, of *experiment*, of *pure physiology*. I beg my readers to compare § § 114, 29—32, &c. &c. of my Second Memoir.

3. I have reflected, with much satisfaction, that, of my various statements, I have scarcely had one to retract, after all the criticism which has been somewhat lavishly bestowed upon them; and that, of the statements of others, scarcely one has either added any thing to what had been done, or has proved correct. I regard these events as the reward of the care which I had taken to restrain myself, as I have just stated, within the limits of the most obvious facts, and of the most immediate deductions from those facts. Thus I have restricted the reflex actions to the true spinal marrow. Those who have imagined that a similar reflex function belongs to the cerebral or to the ganglionic system, have, I think, only confused the subject, and added what is really hypothesis or conjecture. I have also confined the part performed by the reflex function within its just limits. Some writers, having extended its influence beyond those limits, have again caused a doubt to be cast over the whole system. In the actions of walking in *man*, I imagine the reflex function to play a very subsidiary part, although there are, doubtless, facts which demonstrate that the contact of the sole of the foot with the ground is not unattended by a certain influence upon the action of certain muscles. It is very different in the *bird* and *fish* tribes, as I shall have occasion to explain hereafter.

4. Some writers have taken very unnecessary trouble to prove that the experimental fact of a reflex action has long been known to physiologists; as if this had ever been denied; or as if it had not been admitted in the most express terms. (See my First Memoir, § 107.) Others have even descended to shew that the term "*reflex*" had been employed by former physiologists!* I have never claimed either to have been the first to observe the facts of the reflex action in experiments, or to have been the first to use the term reflex. My real objects have been—

5. First, to separate the reflex actions from any movements resulting from *sensation* and *volition:*

6. Secondly, to trace these actions to an acknowledged source or principle of action in the animal œconomy—the *vis nervosa* of Haller—acting according to *newly-discovered Laws:*

7. Thirdly, to *limit* these actions to *the true-spinal marrow*, with its appropriate *incident and reflex nerves*, exclusively of the cerebral and ganglionic systems:

8. Fourthly, to apply the principle of action involved in those facts to *physiology;* viz. to the physiology of *all the acts of exclusion, of ingestion, of retention*, and *of expulsion*, in the animal frame:

9. Fifthly, to trace this principle of action in its relation to *pathology;* viz. to the pathology of the *entire Class of spasmodic diseases:* and

10. Sixthly, to shew its relation to *therapeutics*, and especially to *the action of certain remedial, and certain deleterious, physical agents.*

11. Finally, it is to these objects, taken together as a *whole*, or as a *System*, that I prefer my claims; and I do not pretend that an occasional remark may not have been incidentally made by some previous writer, bearing upon some one or more of them.

* Die Lehre von der Reflex-Function; von Johann Welhelm Arnold; 1842; p. 29.

12. I have always been struck by three remarkable facts:

13. The first, that there should have been a principle of muscular action in the animal œconomy, acknowledged amongst physiologists, the *vis nervosa* of Haller, without any application to physiology:

14. The second, that there should have been a series of experimental phenomena,—certain muscular actions,—untraced, either *backwards* to any *principle* of action, or *forwards* to any *physiological* act:

15. The third, that there should have been a series of functions, and a class of diseases, hitherto unexplained, which the excito-motor principle, just noticed, and involved in those experiments, should be calculated to explain in the most perfect and satisfactory manner.

16. It is these three *desiderata* which I consider I have supplied. It is to the accomplishment of these objects that my claim is limited. It is to these objects, taken together, that I would beg to call the especial attention of my readers.

17. I should not do justice to the subject, if I did not say that I regard it, in its relations, first, to the nature of the principle of action involved in it, and secondly, to its extensive applications to anatomy, physiology, pathology, and therapeutics, as most important. That my labours have been totally unrequited,—nay, that they have been opposed and repulsed,—is not very honorable to our first scientific Institution, to which the first fruits of my labours were offered.

18. No better idea of the importance of this discovery can be adduced, than the total obscurity and confusion which are observed to prevail in the best works on the nervous system, written previously to its promulgation: in Legallois we have the utmost confusion in regard to sensation and volition in their relation to their seat in the nervous system, and to the reflex motions; in the work of M. Brachet, we have the same confusion

in reference to the reflex actions and the functions of the ganglionic system; and every physiologist remembers, what is so forcibly expressed by Prof. Müller, that this latter part of the nervous system was supposed to explain all the sympathies: "Die Erklärungen der Sympathien durch den N. Symphaticus erklären alles und wieder gar nichts*;" whence the designation great sympathetic.

19. Having, on a former occasion (Memoir II, p. 53—), sufficiently refuted the claims of several writers, both of remote and recent date, in regard to the subject of my labours, I shall only, in this place, make a very few and brief remarks on the imagined similarity between the views of Prochaska and my own.

20. Let any one compare the distinct detail of my views just given in §§ 5—11, with the observations of Prochaska, and he will at once discover that there is *nothing* in that author possessing *the most remote similarity* to those views.

21. That the observations of Prochaska are, nevertheless, very remarkable, and calculated to beguile the superficial reader and thinker, I am quite ready to admit. For example, he observes—"Impressiones externæ, quæ in nervos sensorios fiunt, per totam eorum longitudinem celerrime ad originem usque propagantur; quo ubi pervenerunt, reflectuntur certa lege, et in certos ac respondentes nervos motorios transeunt, per quos iterum celerrime usque ad musculos propagatæ motus certos ac determinatos excitant. Hic locus, in quo tanquam centro nervi tam sensui quam motui dicati concurrunt, ac communicant, et in quo impressiones nervorum sensoriorum reflectuntur in nervos motorios, vocatur, termino plerisque Physiologis jam recepto, sensorium commune.

22. "Totum cerebrum cerebellumque certe non videtur ad sensorium

* Handbuch der Physiologie, Band I. Ed. 1. p. 689.

commune constituendum spectare, quæ partes systematis nervosi videntur potius instrumenta esse, quibus anima immediate utitur, ad actiones suas, animales dictas, peragendas; sed sensorium commune proprie dictum se per medullam oblongatam, crura cerebri cerebellique; etiam thalamorum opticorum partem, et totam medullam spinalem, verbo, quam late patet nervorum origo, extendere non improbabile utique videtur. Ad medullam spinalem usque sensorium commune extendi docent motus in animalibus decapitatis superstites, qui sine nervorum ex medulla spinali oriundorum consensu ac commercio fieri non possent; nam rana decapitata si pungitur, non tantum punctam partem retrahit, verum etiam repit, et saltat, quod absque consensu nervorum sensoriorum et motoriorum fieri nequit, cujus consensus sedes in medulla spinali, superstite sensorii communis parte, sit oportet.

23. " Impressionum sensoriarum in motorias reflexio, quæ in sensorio communi fit, non peragitur juxta solas leges physicas, ubi angulus reflexionis æqualis est angulo incidentiæ, et ubi, quanta fit actio, tanta etiam sequitur reactio; sed leges peculiares, a natura in pulpam medullarem sensorii quasi scriptas, sequitur ista reflexio quas ex solis effectibus tantam noscere, neutiquam vero assequi ingenio nostro valemus. Generalis tamen lex, qua commune sensorium impressiones sensorias in motorias reflectit, est nostri conservatio: ita ut impressiones externas corpori nostro nocituras sequantur certæ impressiones motoriæ, motus producturae eo collimantes, ut nocumentum a corpore nostro arceatur, amoveaturque; et vice versa impressiones externas seu sensorias, nobis profuturas, sequantur impressiones internæ seu motoriæ, motus producturæ eo tendentes, ut gratus ille status ultro conservetur. Hanc generalem reflexionum sensorii communis legem probant certe plurima exempla, quæ adduci possent, quorum pauca tantum adduxisse sufficiet. Irritatio in membrana narium interna facta excitat sternutationem, quia impressio illa ab irritatione in

nervis olfactoriis facta per eos ad sensorium commune defertur, ibi certa lege reflectitur in nervos motorios, musculis respirationi dicatis prospicientes, et per hos validam expirationem per nares producit, qua per aërem vi transeuntem irritamentum avellitur, et ejicitur. Ita fit, ubi irritatio in aspera arteria per micam cibi, vel guttulam potus illapsam causatur: facit hæc irritatio ad sensorium commune delata, et ibidem in nervos respirationis motui dicatos reflexa, ut excitetur valida tussis, aptissimum ad expellendum irritamentum remedium, quæ prius non desinit, donec irritamentum ejectum non fuerit." And—" Cum itaque præcipua functio sensorii communis consistat in reflexione impressionum sensoriarum in motorias, notandum est, quod ista reflexio vel anima inscia, vel vero anima conscia fiat." But then he adds—" Si amicus digito suo appropinquat ad oculum nostrum, licet persuasissimus nihil mali nobis inferendum esse, tamen jam impressio illa per opticum nervum ad sensorium commune delata, in sensorio ita reflectitur in nervos palpebrarum motui dicatos, ut nollentibus claudantur palpebræ, et arceant molestum digiti ad occulum attactum." And—" Sed fieri tamen reflexiones impressionum sensoriarum in motorias in ipso sensorio communi anima prorsus nescia docent actiones quædam in apoplecticis, quibus tota conscientia ablata est, superstites: nam et pulsu forti gaudent, et valide respirant, et etiam manum elevant, locoque affecto persæpe admovent inscii." And again—" Motus cordis, ventriculi, et intestinorum certe ab animæ conscientia nequaquam pendent, cum tamen nullus motus muscularis cieri possit, nisi stimulus nervis sensoriis applicatus in nervos motorios reflexione quadam transeat, et musculi contractionem cieat, tunc certum est reflectionem impressionum istis motibus excitandis aptarum, si in sensorio communi fiunt, fieri sine animæ conscientia*."

* Opera Minora, t. ii, p. 150.

24. It is impossible to adduce specimens of more complete confusion than these, in which *voluntary* acts, and the actions of the *heart*, *stomach*, and *intestines*,—functions of the *cerebral* and of the *ganglionic* systems respectively,—are arranged with certain reflex experimental facts and *very obvious* sympathetic actions, which really belong to the *true spinal* system!

25. It is surely needless to add another remark upon this author. I will therefore only further observe, or rather repeat, that we have not, in *any* author, the idea of the true *reflex* action of the *vis nervosa*, or of a *reflex physiological* act; that no one had detected the *reflex* nature of the physiological acts of *Respiration*, or discerned the system of *incident respiratory nerves*; that no one had detected the *centric* and *vascular* origin of the actions in *Asphyxia*, as distinguished from these: in a word, that no one had pointed out the true spinal system, its anatomy, and its application to physiology, pathology, and therapeutics.

§ II. *General View of the Nervous System.*

26. The nervous system has long been divided into *the cerebro-spinal*, and *the ganglionic*. The very designation of the former of these two subdivisions of the general nervous system excludes the idea of a third, which I have, from its central organ, the spinal marrow, as distinguished from the intra-spinal chord of cerebral nerves, termed *the true spinal*. I now, therefore, propose to divide the nervous system into—

I. *The Cerebral*,
II. *The True Spinal*, and
III. *The Ganglionic*.

27. The cerebral system is the seat of the special senses, of perception, of judgment, and volition, of the mental faculties generally, and of the emotions, passions, and sensations; and therefore of the ψυχη, or immortal soul. The central organ is the cerebrum. To this organ all the nerves of the special senses, the olfactory, the optic, the acoustic, &c. are attached; and from this organ all those nerves which are conductors of volition, the motor oculi, the intra-spinal voluntary nerves, &c. proceed.

28. The cerebellum appears, according to the investigations of M. Flourens, to exist intermediately between the cerebrum and the voluntary nerves, as the combiner, the controller, the regulator, of the voluntary motions.

29. The knowledge of the due limitation of this system we owe to the admirable investigations of the author whom I have just quoted, whose work* is a model for physiological investigation.

30. Legallois had erroneously extended the seat of sensation and volition to the spinal marrow. In order to prove this, he adduces an experiment:

31. " Cette expérience consiste à couper transversalement la moëlle épinière entre la dernière vertèbre dorsale et la première lombaire dans un lapin âgé de vingt jours ou moins. Après cette opération, le sentiment et les mouvemens volontaires continuent d'avoir lieu, même dans le train de derrière. Mais il n'y a plus aucun rapport de sentiment ni de mouvement entre les parties antérieures et les parties postérieures à la section de la moëlle; c'est-à-dire, que si l'on pince la queue ou bien une des pattes postérieures, tout le train de derrière s'agite, mais celui de devant n'en paraît rien ressentir, et il ne bouge pas. Réciproquement, si l'on pince une oreille ou une des pattes de devant, les parties anté-

* Recherches sur les Propriétés du Système Nerveux; 2nd Edit.

rieures s'agitent, mais les postérieures demeurent tranquilles. En un mot, la section de la moëlle a évidemment établi, dans le même animal, deux centres de sensations bien distincts et indépendans l'un de l'autre; l'on pourrait même dire deux centres de volonté, si les mouvemens que fait le train de derrière, quand on le pince, supposent la volonté de se soustraire au corps qui le blesse.*"

32. The concluding line of this quotation seems to betray a little doubt in the author's mind in regard to the localization of volition in the spinal marrow. In other parts of his estimable work, however, no such doubt is expressed. He observes—" Il est facile de démonstrer que cette prérogative de la moëlle épinière, d'être la source du sentiment et de tous les mouvemens volontaires du tronc, lui appartient exclusivement à tout autre organe†."

33. It has been, I believe, fully ascertained, by my own investigations, that, when the influence of the cerebrum is cut off, as in cases of paraplegia in the human subject, and in experiments in animals, perception and volition are removed, and all voluntary motion abolished, and that the phenomena adduced by Legallois are dependent on another and entirely different, and *physical*, principle of action.

34. I have mentioned, § 27, that the cerebral system is the seat of the emotions, passions, and sensations. There is good reason for supposing that the medulla oblongata is the more especial seat of these faculties. This part of the nervous system seems, indeed, to be the precise point where the psychical and physical functions are *combined;* the cerebrum being otherwise the exclusive organ of the former, the true spinal marrow of the latter.

* Œuvres de Legallois, Paris, 1824, tome i, p. 80.

† Op. cit. p. 62.

35. When the cerebrum and cerebellum are removed, and with these all perception, volition, &c., there is still the unequivocal expression of *pain*, when any part naturally endowed with great sensibility is forcibly seized by the forceps.

36. For observations on the connection of the emotions and passions with the medulla oblongata, I beg to refer to my former Memoir (Memoir II, § 173—, 182—), and my late volume on the Diseases and Derangements of the Nervous System, p. 252—, &c.

37. Legallois has ascertained that that part of the medulla oblongata which gives origin to the pneumogastric nerves, is *essential* to the acts of respiration; but he erroneously concluded that it is the *primum mobile* of those acts. He observes—" Ce n'est pas du cerveau tout entier que dépend la respiration, mais bien d'un endroit assez circonscrit de la moëlle allongée, lequel est situé à une petite distance du trou occipital et vers l'origine des nerfs de la huitième paire.*"

38. That the medulla oblongata is essential to the acts of respiration, is determinately proved by all subsequent experiments, but especially by M. Flourens, from whose work I must give the following lengthened and important extract:

39. " I. En résumant tout ce qui précède, on voit:

40. " 1°. Que les lobes cérébraux, le cervelet, les tubercules bijumeaux ou quadrijumeaux, la moëlle lombaire, la portion inférieure de la dorsale, n'interviennent point directement dans la respiration;

41. " 2°. Que la moëlle cervicale et la moëlle costale y interviennent comme agents immédiats et déterminés de certains mouvemens inspiratoire;

42. " 3°. Et que la moëlle allongée y intervient seule comme premier mobile et comme principe régulateur.

* Op. cit. p. 64; compare p. 237, 247, 259; &c.

43. " II. Lorry et Le Gallois, conduits par des routes diverses, avaient pourtant reconnu tous deux, qu'il existe un point, dans la moëlle épinière et dans le voisinage de l'encéphale, dont la destruction anéantit sur-le-champ tous les mouvemens inspiratoires.

44. " L'un plaçait ce point entre les première et deuxième vertébres du cou ; l'autre le plaçait, plus exactement, vers l'origine de la huitième paire.

45. " Mais nul ne se faisait une idée juste de la manière dont il s'agit ; l'un n'y voyait qu'un grand mystère de la puissance nerveuse ; l'autre, qu'une loi primordiale de cette puissance, ce qui n'était encore qu'un mystère un peu différemment exprimé ; nul enfin n'y voyait la source, d'un ordre entier de mouvements ; je veux dire de tous les mouvements coordonnés de conservation.

46. " La respiration n'est pas, en effet, le seul mouvement qui tire de ce point son premier mobile. Tous les mouvements derivés da la respiration, le cri, le bâillement, etc. y puisent aussi leur premier principe.

47. " Je retranchai, sur un lapin, toutes les parties cérébrales, à l'exception de la moëlle allongée : non seulement cet animal respirait bien encore ; mais, quand on le pinçait fortement, il s'agitait et criait.

48. " Certaines déjections alvines ou viscérales, etc. exigent, dans l'état naturel, comme chacun sait, le concours de plusieurs parties diverses et éloignées. Or, tant que la moëlle allongée subsiste, ce concours s'opère ; il ne s'opère plus dès qu'elle est détruite.

49. " La moëlle allongée est donc le premier mobile de l'inspiration, du cri, du bâillement, de certaines déjections ; ou, en termes plus généraux, et comme je le disais tout-à-l'heure, de tous les mouvements coordonnées de conservation*."

* Op. cit. p. 180—183.

50. M. Flourens agrees with Legallois also in regarding the medulla oblongata not only as *essential* to the acts of respiration, but as the *primum mobile*, or as the intrinsic excitor of the acts of respiration†. I have proved, I believe, that the prime movers or excitors of respiration are, in the first instance, the trifacial and the spinal nerves distributed to the several surfaces of the face and trunk, and, in the second, to the pneumogastric nerves distributed to the air-cells in the lungs; that the *physiological* acts of respiration are, in a word, excited reflex acts, excited through the medium of the nerves which I have just enumerated; and that the medulla oblongata is the essential centre between these and the nerves arranged by Sir Charles Bell as the motors of respiration. The experimental facts on which M. Flourens has founded his opinion, admit of the readiest explanation on this principle, and indeed are its natural and essential consequences, as I shall explain more particularly hereafter.

51. The medulla oblongata seems, therefore, to be the central organ both of psychical and excito-motor phenomena, and to differ from the cerebrum in possessing the latter faculty, and from the spinal marrow in possessing the former. It is, like certain nerves, *mixed* in its functions and the common boundary of the cerebral and true spinal systems inclusive. It is probably by irritating the medulla oblongata that tumors in the median lobe of the cerebellum excite the sexual faculty and organs.

52. Of the true spinal marrow I propose to treat somewhat at length in the subsequent pages. I need not, therefore, do more than briefly advert to it in the general view of the nervous system which forms the subject of this section.

53. With the true spinal system the ganglionic system is in immediate connection. This latter is divided into—1, the *external*, comprising the ganglia on the posterior roots of the spinal nerves, and destined for the

† Op. cit. p. 183; 189—.

nutrition and other organic changes which take place in the external organs,—the organs of sense, of motion, &c.; and 2, the *internal*, destined for the nervous supply of the internal organs, influencing and governing the actions of the heart, the stomach, and the intestines, the organs of nutrition and secretion, &c.

54. I think it unnecessary to add any account of the discoveries of Sir Charles Bell. To do justice to them would be to occupy too much space, and they are too well known to render this necessary. In reference to my present object, it is that which has been so well expressed by Prof. Valentin by the term *Lex Belliana*, to which I ought more particularly to advert; and every physiologist is now intimately acquainted with this most important, or, to use the emphatic expression of Prof. Müller, this "second" discovery in physiology.

55. In giving this general view of the nervous system, I have retained the very words of the authors whom I have quoted. I have done this on principle, in order that I might avoid, what I so often observe in other writers, viz. any misstatement of their views.

ON THE

TRUE SPINAL MARROW, &c.

PART I.

SECTION I. *The Excito-motor Power.*

§ I. *Seat of the Excito-motor Power; its Modes of Action; &c.*

56. THE nervous system may be divided into different portions, according as they are endowed or unendowed with the excito-motor power: thus, in general terms, the cerebrum and cerebellum are *in*-excitor; the medulla oblongata and medulla spinalis are excitor; the nerves of special sense are *in*-excitor; the trifacial and the analogous spinal nerves are incident excitor nerves; the nerves distributed to muscles are direct excitors; the ganglionic system is excito-motor, but, for reasons which will be given hereafter, in a less prompt and energetic degree.

57. The nervous system may therefore be viewed in its cerebral or in-excitor, its true spinal and excitor, and its ganglionic or slowly excitor, portions.

58. The in-excitor portions of the nervous system coincide with the seat of the mental functions. The excitor portions are chiefly dedicated

to the acts of ingestion and egestion. The less excitor or ganglionic portions are the nervous agents in secretion, &c.

59. The true limits of the excito-motor power have been accurately determined by M. Flourens, who also ascertained that, whilst this property acts in a direct manner in the medulla oblongata, the medulla spinalis, and the muscular nerves, its action is *crossed* from the tubercula quadrigemina, or, rather, the peduncles.

60. These views are contained in the following extract from the "Recherches sur le Système Nerveux:"

61. "Ainsi: 1°. Les hémisphères cérébraux ne sont point susceptibles d'exciter immédiatement des contractions musculaires.

62. "Haller et Zinn l'avaient déjà reconnu pour les parties supérieures; Lorry pour le corps calleux: je l'ai vérifié pour tout l'ensemble des hémisphères, les corps striés et les couches optiques.

63. "C'est à tort qu'on a attribué la paralysie des iris à la lésion de ces dernières parties. On peut les couper, ou les piquer sur tous les points, sans abolir comme sans provoquer la contractilité des iris.

64. "Quelques observateurs ont cru exciter des contractions et des convulsions, dans les mammifères, par les piqûres des corps calleux; c'est que ces piqûres s'étendaient jusqu'aux pédoncules cérébraux.

65. "2°. Le cervelet n'excite point non plus immédiatement des contractions musculaires.

66. "Haller et Zinn se sont trompés, quand ils ont dit que les blessures du cervelet causent des convulsions universelles: cela n'est vrai que de la moelle allongée placée au-dessous du cervelet, et probablement intéressée dans leurs expériences.

67. "3°. Dans les oiseaux, les tubercules bijumeaux excitent des convulsions.

68. "Leur irritation, comme celle des nerfs optiques, provoquent les

contractions de l'iris. C'est avec ces tubercules que commence ou que finit, dans cette classe, *l'excitabilité.*

69. " 4°. La moelle allongée, comme la moelle épinière et comme les tubercules bijumeaux, excite des contractions*."

70. " Dans les mammifères, toute la portion supérieure des tubercules quadrijumeaux est impassible.

71. " J'ai piqué, sur des chiens, sur des lapins, sur des cochons d'Inde, &c. toute la portion supérieure, toutes les couches superficielles des tubercules quadrijumeaux, sans exciter des contractions.

72. " J'en ai toujours excité, au contraire, quand j'ai piqué les couches profondes, c'est à dire les *pédoncules* même du cerveau, sur lesquels les *tubercules quadrijumeaux* reposent.

73. " *L'excitabilité* qui, dans les oiseaux, s'étend jusqu'aux *tubercules*, finit donc un peu plus tôt dans les mammifères. Voilà pour la limite des couches supérieures de l'encéphale. Quant à la limite des couches inférieures, elle est la même dans les deux classes: dans les oiseaux, comme dans les mammifères, c'est avec les *pédoncules* du cerveau que *l'excitabilité* finit ou commence†."

74. The same eminent physiologist has determined the question of the *direct* and *crossed* effect, and gives the result of his inquiries in the following terms:

75." Le retranchement d'un seul lobe cérébral, d'un seul côté du cervelet, ou d'un seul tubercule bijumeau, produit constamment une faiblesse plus marquée dans le côté du corps opposé au lobe, au tubercule, ou au côté du cervelet enlevé;

76. " Les lobes, le cervelet, les tubercules ont donc un *effet croisé;* et les lobes et les tubercules, un *effet croisé double:* en avant sur les yeux; en arrière sur les autres parties du corps.

* Op. cit. p. 20—23. † Op. cit. p. 23.

77. "L'irritation d'une seule moitié latérale, soit de la moelle allongée, soit de la moelle épinière, détermine toujours des convulsions du même côté;

78. "Et pareillement, la mutilation d'un seul côté de la moelle épinière ou de la moelle allongée ne paralyse que les parties de ce côté;

79. "La moelle épinière et la moelle allongée n'ont donc qu'un *effet direct.*"

80. Lastly, M. Flourens had observed the retrograde action of the excito-motor property in an experiment, in which the spinal marrow had been laid bare in a pigeon:

81. "De plus, lorsque j'irritais à une égale distance des deux renflements, les convulsions se manifestaient également aux jambes et aux ailes;

82. "Lorsque, au contraire, j'irritai en-deça on au-delà de ce point mitoyen, les convulsions prédominaient, ou même, si l'irritation etait légère, se bornaient aussitôt ou aux jambes ou aux ailes, selon que le point irrité était plus voisin des unes ou des autres*."

83. Such, with the statements quoted from Haller and Prof. Müller, in my second Memoir, was the condition of our knowledge of the excito-motor property, when I was led to prosecute the inquiry into a question which had been certainly overlooked by physiologists; viz. What is the application of this extraordinary power to physiology?

84. To this inquiry, I was led by a series of experimental *facts*, not less known to physiologists, to which I have already adverted; § 14. These facts themselves, indeed, suggested a similar question; viz. What analogical actions are there in the animal œconomy?

85. It was not to be supposed that a *principle* of action, and a *form* of action, should exist in the animal frame without application to its functions. And yet no such application of the excito-motor power, evidenced in one

* Op. cit. p. 118, 113, 114.

series of experiments, or of the reflex form of action, evidenced in another, had been made by physiologists to the œconomy of animal life; nor had the remotest conjecture been expressed that these two series of experiments depend, as I have demonstrated, on one and the same principle of action. Indeed, the *law* of action of the vis nervosa, as laid down by Haller and Prof. Müller,—that it is *always* and *only* in the direction *from* the nervous centres,—was incompatible with such an opinion.

86. Reflecting on the *facts*, it occurred to me that the excito-motor property *might* act according to undiscovered laws, and *might* be not only the agent in the reflex actions observed in experiments, but also in certain physiological acts. In order to establish this principle, it was, in the first place, necessary to demonstrate a *reflex* mode of action of the *vis nervosa.* This could only be done by experiment, and I immediately entered upon the interesting and important inquiry.

87. That the view which I have given of the opinions of physiologists is just, is evinced by the following extracts from Haller, Bichât, Cuvier, and Professor Müller:—

88. Haller observes,—" Irritato nervo, convulsio in musculo oritur, qui ab eo nervo ramos habet. Irritato vero nervo, multis musculis communi, totive artui, omnes ii musculi convelluntur, qui ab eo nervo nervos habent, sub sede irritationis ortos. Denique medulla spinali irritata, omnes artus convelluntur, qui *infra* eam sedem nervos accipiunt; *neque* contra artus, qui *supra* sedem irritationis ponuntur." He concludes, " conditio illa in nervo, quæ motum in musculis ciet, *desuper* advenit, sive a cerebro et medula spinali, *deorsum*, versus extremos nervorum fines propagatur;" and " ut adpareat *causam motus a trunco nervi in ramos, non a ramis in truncum venire**."

* Elementa Physiologiæ, Lausannæ, tome iv. page 325.

89. Bichât observes:—"L'influence nerveuse ne se propage que de la partie supérieure à l'inférieure, et jamais en sens inverse. Coupez un nerf en deux, sa partie inférieure irritée fera contracter les muscles subjacens; on a beau exciter l'autre, elle ne détermine aucune contraction dans les muscles supérieurs; de même la moelle, divisée transversalement et agacée en haut et en bas, ne produit un effet sensible que dans le second sens. Jamais l'influence nerveuse ne remonte pour le mouvement, comme elle le fait pour le sentiment*."

90. Cuvier, in his report on the admirable work of M. Flourens, observes:—"Toute irritation d'un nerf le met en jeu dans les muscles, *où il se rend.* Toute irritation de la moelle la met en jeu dans les membres placés *audessous* de l'endroit irrité†."

91. Professor Müller expresses himself in the following very express terms:

92. "The motor power in the nerves acts only in the direction of the primitive fibres proceeding to the muscles, or in the direction of the ramification of the nerves, *and never in a retrograde direction*;" and, "All motor fibres act in an isolated manner *from* the trunks of the nerves *to* the smallest ramifications‡."

93. As long as these views were entertained by physiologists, there could be no application of their principle of action, discovered by *experiment*, to actual *physiology*; for, with *one* exception, that of the tone of the muscular fibre, *every* physiological action of the *vis nervosa*, or the excito-motor power, proceeds along the nerves, in the first instance, in an incident direction *from* their ramifications *towards* their trunk, and thence *into* the true medulla, *from* and *by* which latter it is *reflected* along other nerves in the direction described by the physiologists whom I have quoted.

* Anatomie générale, 1801, tome iii. page 277.

† Op. cit. p. 83-84.

‡ Handbuch, ed. i. p. 656, 659.

94. I have, however, ascertained, by a series of *experiments*, that the excito-motor power does act in these incident and reflex directions; and I consider the correction of the former error, and the establishment of this fact, as the first step towards the application of this power to the science of physiology.

§ II. *Newly-ascertained Laws of Action of the Excito-motor Power.*

95. I cannot unfold this subject better than by a description of *Plate* I.

96. Fig. 1, *a*, represents the influence of a stimulus applied to a muscular nerve, upon the muscular fibre to which it is distributed; that fibre is excited into contraction. The phenomenon is the simplest of those presented by the *vis nervosa* of Haller, the *vis motoria* of Prof. Müller; see § § 88, 92.

97. Fig. 1, *b*, presents us with the same phenomenon in a form a little more complicated. If a stimulus be applied to the spinal marrow itself, all the muscles which receive nerves from below the point irritated are excited into convulsive action. This again is the *direct* effect of the *vis nervosa*, as described by Haller, Bichât, Prof. Flourens, Prof. Müller, &c.

98. To these *direct* phenomena of the *vis nervosa*, and to the *law* naturally flowing from them, the views of former physiologists were limited, at least with the exception of M. Flourens, given at § § 81, 82. Hence the conclusions drawn from them and given § § 88, 92.

99. But in Fig. 2, we have the commencement of a new order of phenomena. When the spinal marrow is stimulated in its middle part, *a*, after decapitation, *both* the anterior and the posterior extremities are

moved, muscles receiving their nerves both from *above* and *below* the point irritated being excited into contraction; an event at variance with the *law* of the exclusively *direct* action of the *vis nervosa* laid down by Haller, Prof. Müller, &c.

100. If the point *b* be stimulated, a point situated nearer the anterior than the posterior extremities, the anterior extremities are even more excited than the posterior; that is, the *retrograde* action of the *vis nervosa*, or excito-motor power, is greater even than its *direct* action and its more distant manifestation.

101. If a point *c*, nearer the posterior extremities than the anterior, be stimulated, both are moved, but the former more than the latter; the energy of the direct action being always greater under these circumstances, whilst the distance is also less. Compare §§ 81, 82.

102. Fig. 3 demonstrates a mode of action both distinct from the former and entirely new. If a lateral nerve, running from the spinal marrow, and truncated at a certain distance from it, be stimulated, the anterior and posterior extremities are again moved by the contraction of their muscles. The excito-motor power acting first in an *incident* direction *towards* the spinal marrow, then in a *reflex* manner *within* the spinal marrow, and lastly in a direction *from* the spinal marrow and *towards* the muscular system.

103. If a nerve, *a*, near the anterior extremities, be stimulated, the muscles of these extremities are most moved; if a nerve, *b*, near the posterior extremities be stimulated, these are most moved in their turn; if a nerve, *c*, intermediate in its situation be stimulated, the anterior and the posterior extremities may be moved equally.

104. It will be observed that these facts are in direct opposition to the exclusive *law* of action of the excito-motor power, propounded by Haller, Prof. Müller, &c. They establish, indeed, a *new Law of action* of this

power, on which the whole of its *physiology* depends.

105. Fig. 4 represents a new fact in the action of the *vis nervosa* or excito-motor power.

106. In the experiments described § 103, it is obvious that a compound nerve was subjected to stimulus. In the present case, we first irritated the *posterior* and then the *anterior* column of the spinal marrow: in the former case, we observed movements of the four extremities and of the tail; in the latter, we induced similar movements, still more energetic in their character. We then irritated, first the *posterior*, and then the *anterior* roots of the spinal nerves, with similar effects.

107. These last experiments must have presented an obstacle to the demonstration of the *Lex Belliana*, had not the facts and principles of the *reflex* action of the *vis nervosa* been discovered. They present, too, examples of a series of facts of the utmost interest, both to the physiologist and the pathologist.

108. We are led by these views to a series of phenomena, known, but not hitherto explained or reduced to any law of action. Fig. 5 represents the effects of stimulating, not the nerve itself, not the spinal marrow, but the integument: effects precisely similar to those to which Figs. 2 and 3 refer, are produced. But these are the very facts long known to physiologists, and, as I have said, hitherto unexplained and unapplied.

109. Another circumstance, connected with this experiment, requires especial notice. The phenomena thus introduced by stimulating the very *extremities* of the nerves are more energetic and distinct than those induced by stimulating their *trunks*.

110. This fact I noticed long ago in my Second Memoir, § 21. Its discovery has been ascribed to Prof. Volkmann. I first observed it distinctly in experimenting on the frog: having removed the head, I divided

the integuments over the spine; raising these up by means of the forceps, numerous nerves were displayed: on irritating these, frequently no motor phenomena were produced; whereas, on irritating the skin to which the nerves were distributed, all the limbs were moved.

111. Fig. 6 represents several of the phenomena which have been detailed, as they occur in the separated head of the turtle: if the extremity of the spinal marrow be irritated, a *retrograde* action of this excito-motor power takes place, and an act similar to that of respiration occurs. The same phenomenon is excited on stimulating the end of the pneumo-gastric nerve, arising from the incident action of the same power; and the same phenomenon occurs on irritating the fine extremities of the tri-facial nerve in the nostril.

112. Fig. 7 represents the action of the sphincter ani, excited by irritating the cutaneo-mucous membrane on its border, an *incident reflex* action carried *to* and *from* the spinal marrow by the incident and reflex nerves of the part.

113. Lastly—Fig. 8, *a*, *b*, *c*, and *d*, denote the general forms and modes of action of the excito-motor power; *incident* and *reflex* at the upper and lower parts of the spinal marrow; incident and reflex, and *from above downwards*, as in the case of strangury induced by dentition; incident and reflex, and *from below upwards*, as in the case of grinding of the teeth from irritation of the rectum—forms and modes of action which cannot be studied with too great care, by the pathologist especially.

§ III. *Nature of the Excito-motor Power.*

114. Nothing is known, in reality, of the *nature* of the *vis nervosa*, or excito-motor power; as nothing is known of the *nature* of caloric, galvanism, &c., to the latter of which it may be aptly compared. The *phenomena* and the *laws of action* of that power are the only objects of physiological investigation; and these I have endeavoured to ascertain, to unfold and describe, and to apply.

115. Sir W. F. Herschel has imagined that the brain may be of the nature of a galvanic apparatus; it is far more probable that the spinal marrow, and the system of excito-motor nerves during their whole length, intimately associated as they are with the arterial system, are of this character. At any rate, the excito-motor power may, without hypothesis, be viewed as bearing the same analogy and relation to its phenomena in physiology, as galvanism does to its phenomena in physics. It will thus present to our minds the idea of an essence, as distinct from mind as its phenomena are distinct from that of sensation, volition, &c.

116. In addition to what has been already stated, I may here observe that, like galvanism, the excito-motor power admits of *augmentation* and *diminution*—of *diminution* and *restoration*. Its measure depends greatly on the condition of the blood, and on the force of the circulation within the spinal marrow, especially in the warm-blooded animals, and on some inscrutable condition apparently of the nervous fibre or mass themselves.

117. The excito-motor power is diminished or augmented by certain conditions of its central organ, the true spinal marrow. It is diminished by the loss of its blood, and of the arterial character of its blood; it is restored after this deterioration by that of the normal condition of the circulation.

118. This fact is illustrated by experiments detailed by Legallois*, who observes—"J'ai répété sur plusieurs l'expérience de l'insufflation de l'air dans les poumons, après avoir attendu que la sensibilité fût éteinte, et je suis parvenu à la ranimer ainsi que les mouvements du corps à un tel degré que les animaux s'agitaient par le plus leger pincement," &c.

119. The same circumstance has been observed in the frog by Prof. Müller and myself, although I think that eminent physiologist has deduced two erroneous inferences from it† :—1. The circulation of arterial blood is the *condition*, not the *cause* of the acts of inspiration, and can by no means be the cause of the *first* inspiration, that is of itself. 2. The medulla oblongata is not the "primum" movens of the respiratory movements, though it again may be the essential condition of these movements. But the *facts* related by this eminent physiologist are of the most interesting character.

120. "The cause of the first respiration can only be the impression made on the medulla oblongata by the arterial blood, which is formed in consequence of the first entrance of the air into the respiratory organs, and in less than a minute reaches the primum movens of the respiratory movements in the central organs of the nervous system. The arterial blood is also very beautifully shewn to be the cause of the continuance of the respiratory movements throughout life, by my experiments on frogs, in which I made the animals breathe for several hours in hydrogen; after a time, respiration ceased, although life was not extinct. For a time, the respiratory movements were renewed, when the vessel in which the animals were included was agitated; but, after a longer period had elapsed, this was no longer the case. If, after being thus confined in hydrogen for

* Expériences Physiologiques sur les Animaux; p. 57—.

† Elements of Physiology, by J. Müller, translated by W. Baby, M.D.; vol. ii. p. 919.

two or three hours, the frogs are taken out and exposed to the atmosphere, they appear perfectly dead, not the least sign of motion or sensation is observable in them." "The first sign of the revival of the frog, which lies quite motionless, is the retraction of the extremities when the skin is pinched; after a short time, it is seen to respire at long intervals, and in a few hours is quite lively. The cause, therefore, of the first excitement, and of the continued action of the medulla oblongata, in determining the respiratory muscles to action, is the arterial blood."

121. The fact observed by myself was that of a frog, in which I had divided the spinal marrow near the cranium, and which I had left immersed in water:—The excito-motor power seemed to have ceased; there was no respiration, no movement on irritating the toes; on being removed from the water, and placed in the free open air, respiration and the excited reflex movements were gradually restored. It is obvious that the animal was asphyxiated in the first instance, and that the arterial character of the blood was restored, and with it the energy of the excito-motor power, in the second.

122. The excito-motor power is morbidly augmented by a physical action, induced through the excito-motor nerves in tetanus, and by a poisoned condition of the blood in hydrophobia. It is augmented in some cases by the condition induced in the divided portion of the medulla in the decapitated animal, and by the poisoned condition of the blood after the administration, or application, of strychnine. In an experiment performed by Mr. H. Smith and myself, in which we divided the cervical spinal marrow in a very young kitten, the trunk of the animal became as susceptible of external impressions, manifested by reflex actions, as in the case of tetanus itself.

123. It is also worthy of special observation, that, in the very young animal, and in the cold-blooded animal, the phenomena of the excito-

motor power are far more vividly manifested than in the older and the warm-blooded. In the very young kitten, even when asphyxiated to insensibility, every touch, contact, or slight blow—every jar of the table, any sudden impression of the external air, or that of a few drops of cold water—induces at once energetic reflex movements and acts of inspiration. The nostrils, the tail, the soles of the feet, the general surface, are all extremely susceptible, and in degree in the order in which I have mentioned them. Hence, nature's provision for the first establisment of the first acts of inspiration, and of extra-uterine life. Hence, the principle of resuscitation from congenital asphyxia; a subject to which I shall recur in the sequel.

124. *Immediately* after decapitation, or the sudden amputation of a limb, a diminished condition of the reflex excito-motor power is observed:—I divided the spinal marrow in a frog; the reflex actions ceased; in a few minutes they re-appeared, and in a short time they were perfectly restored. I remember the late Capt. Kater relating an experiment in which the legs of the tipula (*long-legs*) were removed by means of a pair of scissors, successively, without any manifestation of pain, or impression of any kind: it was placed under the influence of *shock*.

125. In addition to the sources of excito-motor phenomena already noticed, I must now add another: in irritation of any or all of the internal membranes and tissues, serous, mucous, cellular, &c. by means of the scalpel or forceps, in the kitten or the dog (these were the animals in which I have witnessed these results), various spasmodic movements are observed. What *physiological* object there may be in these phenomena I do not at present perceive; but it is plain that they present a newly-opened and expansive field of investigation to the *pathologist*.

§ IV. *Appearance of Design.*

126. Every physiological act of the reflex excito-motor power is obviously designed; the act of deglutition, the act of inspiration, the closure of the eye-lids, of the larynx, the action of the sphincters;—all is replete with obvious design.

127. How, therefore, the appearance of design in some of the reflex actions observed in experiments should have been imagined, as they have by my venerable friend, Prof. Nasse*, by Prof. Volkmann†, and others, to indicate the presence of a *mental* operation, I cannot comprehend.

128. Thus, if, in the decapitated or divided tortoise, we irritate the various parts *a*, *b*, *c*, in Fig. 9, we observe the several actions portrayed in the plate: if we irritate the tail, the posterior extremities are protruded towards the part, so as apparently to remove the cause of irritation: if we pinch the integuments at *b*, the extremities are retracted; if we irritate the anus, *c*, the limbs are moved so as to be brought into contact with the part.

129. The *design* in all this is obvious; but is it design in the decapitated or divided animal? Certainly not; but of its omniscient Creator! It *coincides* with what would be design in the animal; otherwise, in such acts of the living and perfect animal, the act of volition and the act of the reflex excito-motor powers would counteract and frustrate each other. We may, I believe, be so far allowed to reason from final causes. And may we not be allowed to say, it is all beautiful and demonstrative of the wisdom of Him who fashioneth all things after His own will?

* Untersuchungen zur Physiologie und Pathologie; 1839; p. 255.

† Archiv für Physiologie, von Dr. J. Müller; 1838; p. 22.

130. It is in this manner that the march, the flight,—yes, and the inspiration, of birds and of insects, coincide in effecting the combined objects of loco-motion and of a most vital function. It is in this manner that we are enabled to contemplate the migration of animals, as effected and continued, however long, like the acts of inspiration, on a principle not susceptible of fatigue. I suspect, indeed, that the migratory traveller is frequently actually visited by nature's sweet restorer, during its aërial transit!

131. In this manner the ostrich pursued its course after decapitation by the crescent-headed arrow of the Roman emperor; and the decapitated cock of Kaaw Boerhaave ran on in the direction towards its food, previously impressed by its volition; each successive contact of the foot with the ground *exciting* the subsequent movement.

§ V. *Absence of Sensation and Volition.*

132. I believe but few persons now require to be convinced that in the reflex actions, whether experimental or physiological, neither sensation nor volition bear any essential part. Sensation may accompany, and volition may modify, some of the physiological reflex acts; but, as I have stated, neither is essential. And in the experiments on decapitated animals, the very organ of sensation and volition and the other mental faculties is removed. Still it may be well to place on record the principal proofs of this position.

133. In the first place, then, I beg to call my reader's attention to Fig. 10, *a*, *b*, *c*, *d*, *e*.

134. *a* represents a snake decapitated and suspended by a portion of integument. On irritating the tail, by means of the forceps, it suddenly

assumes the curved position and form portrayed in the drawing; but it very soon falls into the rectilinear position sketched in outline. To repeat the stimulus, is to repeat the phenomena.

135. *b* represents a decapitated snake suspended by a portion of integument, and then raised on the point of a sharp instrument. Can any position be conceived more painful, if sensibility remained? Nevertheless the animal becomes curved when first raised, but speedily falls into the straight position, which it retains without moving; a fresh application of the puncture causing a repetition of the phenomena.

136. *c* represents an experiment described in my First Memoir, p. 9, § 22, and sadly misrepresented by Prof. Volkmann*. A decapitated snake was left on the table, whilst I was summoned to a patient. On my return I found it in the position represented, partly hanging over the edge of the table. No position could be more painful, had the creature been susceptible of pain. Had volition still existed, it would soon have moved into one implying less of suffering. It remained motionless, however, until a new stimulus was applied, when it moved as it had done previously; for the excited motor power was not, as Prof. Volkmann represents, either extinct or even materially diminished. The word 'previous' was overlooked.

137. *d* represents a fact which I have very frequently witnessed, and which may be reproduced with the utmost certainty and facility. If a decapitated snake be laid on the table, it continues to move about, each movement inducing a fresh contact with the table, which proves the excitant of another movement, and so on. But if, by the contact of some soft substance, the movements be gently checked, the animal may be brought into a state of quiescence; and if, when in this condition, it be covered with a bell-glass, so that no agitation of the external air may affect it; and if every other source of excitation, as the slam of the door,

* Müller's Archiv, 1838, p. 37.

walking incautiously over the floor, shaking the table, be avoided; it retains the form and position in which it is placed, unchanged, until all vital phenomena become extinct.

138. *e* is a repetition of what is represented in *a* and *b*, in the frog; if this animal be suspended, as represented, by the legs, after dividing the spinal marrow in the neck, and then any part of the integuments be irritated, it is raised into the position depicted; but it speedily, and then suddenly, *falls* into the position portrayed in outline. Unstimulated, it remains without movement.

139. All these are phenomena of excited action, and, as I imagine, are incompatible with the idea of the existence of sensibility to pain, or of the faculty of volition. Immobility under circumstances of pain, did sensibility exist, proves the absence of such sensibility, the absence of sensation.

140. *f* represents an experiment of Prof. Volkmann, in which he imagines that *spontaneous* motion occurs after the division of the spinal marrow in the neck of the frog, denoting the existence of sensibility. The frog, immediately after the division of the spinal marrow, is drawn out and placed in the position represented in the *outline*. Shortly afterwards, it changed its position, assuming that depicted by *shade*. Afterwards and otherwise, it is admitted that no spontaneous movement is observed. How is this phenomena to be reconciled with the facts already detailed, and how is it to be explained? In the first instance, after the division of the spinal marrow, the animal is under the influence of *shock*, and the excito-motor power, with the reflex actions, are suspended for a time. After a short interval, however, this power with its phenomena return; the limbs stretched out are then stimulated by its firm pressure against the table, and an excited action, with the retraction of these limbs, occurs.

141. In addition to these experiments, I may remind my readers of the case of paraplegia in the human subject. I have seen innumerable cases in which the reflex excito-motor actions were most energetic, but in which there was no sensation, no sensibility whatever, no powers of motion on the utmost efforts of volition.

142. These facts alone determine the question. The subject has been mystified by Dr. J. W. Arnold* and others, by discussions about sensation with, and without, consciousness, as if the latter phrase were not a contradiction in terms; and even Prof. Alison writes in the following manner:—"in order that these sensations may be felt;" as if the phrase were not one of perfect tautology.

143. I need not add any further remark upon the fact of the absence of sensation in the reflex actions of decapitated animals; the proof of the absence of volition consists in the total absence of *spontaneous* motion. I have explained the experiment of Prof. Volkmann; I have expatiated on the facts of the absence of motion in circumstances in which there would be pain and suffering, and the consequent expression of them, if sensibility and volition remained. It appears to me to be unnecessary to pursue the subject. The soul is *one*, and cannot be divided; it cannot exist or manifest itself in *two* portions of the same animal. The paraplegic patient who, being asked whether he felt the puncture which made his limbs move, replied—"No, but my legs do!"—spoke a language which, however emphatic, was unphilosophical and unphysiological. The reader who feels any curiosity in regard to this question, may consult and compare the works of Whytt and Legallois. The former was excessively puzzled by his own admission; the latter admitted the division of the soul, the "*moi*" of the French school, without hesitation or scruple; and both were in error.

* Op. cit. p. 53.

SECTION II. *The Anatomy of the True Spinal System.*

144. My description of the *Anatomy* of the true spinal system will again consist of a detail of *facts*, of experimental facts, and of facts in physiology.

145. The questions are in reality the same as those discussed in the last section—what parts of the nervous system are endowed with the *vis nervosa*, or excito-motor power?—and, through what channels are the phenomena of this power manifested? The replies to these questions present us with the anatomy of the *System;* and there need be no dispute about the matter.

146. The question is further—one of experiment and of physiology. The scalpel may confirm what experiment had determined; but it can do no more. It may suggest experiment; but experiment alone can definitively resolve the problem.

147. The cerebrum, the cerebellum, the olfactory, the optic*, the acoustic nerves, are endowed with the excito-motor power; they do not therefore belong to the excito-motor system. The corpora quadrigemina, the medulla oblongata, the medulla spinalis, the trifacial, the spinal, all† the muscular nerves, are endowed with this power; they do therefore belong to the system. It is a question of fact—of experiment.

* With one exception. † Probably with one exception.

148. The first of these two divisions of the nervous system, whilst unendowed with the excito-motor power, is connected with the psychical or mental functions. The second, *with* the excito-motor power, is also endowed with psychical functions. These are therefore *mixed* in their endowments—mixed in their functions. Of all these latter parts, the medulla oblongata seems to be the *most* mixed (see § 34); and the pneumogastric and levator palpebræ nerves, the *least;* the former of these being almost entirely an excito-motor, the latter almost entirely a voluntary, nerve.

149. In the parts and nerves, in which the two orders of functions are mixed, are they common to *one* kind of nervous fibre, or has each function its seat and course in a distinct order of fibres? This is the *quæstio maximè vexata* amongst the disputants on the subject of the reflex function—the true spinal system. Prof. Volkmann and Prof. Müller have opposed the view of a distinct order of nerves, or of nervous fibres. Dr. Carpenter, who formerly opposed this view, has given in his adhesion to it, led by investigations of his own; so it seems has, more recently, Mr. Newport. I doubt not that the investigations of these gentlemen are correct; they have therefore confirmed what I had long previously done. But it adds nothing, or very little, to the argument, to ascertain that that which is true in one class of animals, proves to be so in another or others.

150. Mr. Grainger asserts that each posterior and each anterior root of the spinal nerves consists in fact of two roots, of which one proceeds along the white columns of the spinal marrow to the brain, whilst the other pursues its course to the grey matter. It is *probable*, therefore, that the former are in reality nerves of sense and voluntary motion, whilst the latter are the nervous channels of the excito-motor power and action. I say it is probable that this is the case. But nothing of this kind has

been *proved:* the two distinct orders of fibres have not been divided or irritated distinctly. The proof can only be afforded by *experiment.* The scalpel suggests this view; but, once more, experiment alone can determine it. The argument, the proof, is, as I long ago stated, *physiological.*

151. It has always appeared to me that, observing the difference between the cerebrum and the spinal marrow, the olfactory and the tri-facial nerves, in regard to the psychical and the excito-motor properties, it is very improbable that in *any* part of the nervous system the two functions should co-exist in any one individual fibre. The difference of function implies a difference of structure; the difference in the physiology implies a corresponding difference in the anatomy. But I am weary of the wordy discussions on the subject; these, therefore, I leave to those who have leisure and taste for them; and I proceed to the detail of the anatomy of the true spinal marrow and system, such as I have viewed it in my own mind, and such as Mr. Simpson has so admirably depicted it in *Plate* II.

THE ANATOMY OF THE TRUE SPINAL SYSTEM.

I. *The Incident, Motor Branches.*

1. *Part of the Optic.*

2. *The Trifacial, arising from—*
   1. *The Eye-lashes.*
   2. *The Alæ Nasi.*
   3. *The Nostril.*
   4. *The Fauces.*
   5. *The Face.*

3. *The Pneumogastric, from—*
   1. *The Pharynx.*
   2. *The Larynx.*
   3. *The Bronchia.*
   5. *The Cardia,—Kidney, and Liver.*

4. *The Glosso Pharygeal?*

5. *The Posterior Spinal, arising from—*
   1. *The General Surface.*
   2. *The Glans Penis vel Clitoridis.*
   3. *The Anus.*
   4. *The Cervix Vesicæ.*
   5. *The Cervix Uteri.*

II. *The Tubercula, the True Medulla Oblongata and Medulla Spinalis, the Centre of the System.*

III. *The Reflex, Motor Branches.*

1. *The Iris.*
2. *The Trochlearis* } *Oculi.*
3. *The Abducens* }
4. *The Minor portion of the Fifth.*
5. *The Facial, distributed to*
   1. *Obicularis.*
   2. *The Levator Alæ Nasi.*
6. *The Pneumogastric or its Accessory.*
   1. *The Pharyngeal.*
   2. *The Œsophageal and Cardiac.*
   3. *The Laryngeal.*
   4. *The Bronchial, &c.*
7. *The Myo-glossal.*
8. *The Spinal Accessory.*
9. *The Spinal, distributed to the*
   1. *Diaphragm, and to*
   2. *The Intercostal and* } *Muscles.*
   3. *The Abdominal* }
10. *The Sacral, distributed to*
    1. *The Sphincters.*
    2. *The Expulsors, the Ejaculators, the Fallopian Tubes, the Uterus, &c.*

152. I believe that, before the date of my investigations, such an idea or view of *incident nerves*, acting in and through their connexion with the true medulla spinalis and certain *reflex motor nerves*, did not exist in anatomy or physiology. It has resulted from my own unrewarded efforts. It has been *justly* regarded and acknowledged by one physiologist only; but then that one holds *the* first rank as a judge in this matter, both from his own incomparable labours and his knowledge of the subject. I need scarcely say that I mean Prof. Flourens: this gentleman observes, in a letter to me, dated Frebruary the 3rd, 1839,—" *Votre beau système des nerfs* excitateurs, incidens *et* réfléchis, *vous appartient bien, et comme grand fait spécial et déterminé, et comme vue d'un grand et nouvel ensemble de phénomènes.*" I consider this testimony as the best reward of my labours.

153. It is plain that whenever a physiological phenomenon exists in nature, and ceases on the division of an isolated portion of the nervous system, its existence and persistence depend on the normal condition of that structure. This view is further confirmed, when the mechanical or galvanic irritation of the same part induces a similar phenomenon. Thus, on the division of the optic nerve, the iris ceases to contract on the admission of light through the pupil; on the irritation of the optic nerve, or that part of it which is attached to the nervous centres, after its division, the iris is excited into contraction. The optic nerve contains, therefore, that which is incident and excitor of the contraction of the iris. The deeply-seated portions of the tubercula quadrigemina are equally essential and efficient in the contraction of the iris. So also is the motor-oculi nerve. In this example we have an instance of a *nervous arc*, which is but one of a whole series or system; the discovery of which as a whole, as a series, as a system, I regard as flowing from my own incessant investigations during many, many years.

154. The anatomical *facts* of the case which I have adduced, we owe to Prof. Flourens*, and to Mr. Mayo†. It is portrayed in the following *Table*:—

ANATOMY OF THE ACTION OF THE IRIS.

I. *The Excitor.*	II. *The Centre.*	III. *The Motor.*
The Excitor portion of the Optic Nerve.	*The Tubercula Quadrigemina.*	*The Motor Oculi.*

155. I subjoin the detail of Mr. Mayo's experiments, on account of their extreme value:—

156. "Thirty pigeons were employed in experiments, of which the following are the results:

157. "1. When the optic nerves are divided in the cranial cavity of a living pigeon, the pupils become fully dilated, and do not contract on the admission of intense light.

158. "2. When the third nerves are divided in the cranial cavity of a living pigeon, the same result ensues: in both these cases the surface of the eyeball retains its feeling.

159. "3. When the fifth nerve has been divided on one side in the cranial cavity of a living pigeon, the iris on that side contracts as usual on the admission of light, but the surface of the eyeball appears to have lost its feeling.

* Op. cit. p. 35; 48; &c.

† Anatomical and Physiological Commentaries, Part II, p. 4.

160. " 4. When the optic nerves are pinched in the cranial cavity of a living pigeon, or immediately after its decapitation, the pupils are contracted for an instant on each injury of the nerves.

161. " 5. When the third nerves are similarly irritated in the living or dead bird, a like result ensues.

162. " 6. When the fifth nerve is similarly irritated in the dead bird, no affection of the pupil is observed.

163. " 7. When the optic nerves have been divided within the cranial cavity of a pigeon immediately after its decapitation, if the portion of the nerves attached to the eyes be pinched, no contraction of the pupil ensues; if the portion adhering to the brain be pinched, a like contraction of the pupil ensues, as if the optic nerves had not been divided.

164. " 8. The previous division of the fifth nerves in the preceding experiment produces no difference in the result.

165. " 9. When the third nerves have been divided in the cranial cavity of the living or dead bird, no change in the pupil ensues on irritating the entire or divided optic nerves."

166. I have mentioned this fact as one of the series, partly from the deep interest attached to it in itself, and partly because it has been adduced as an example of a *cerebral* reflex action by Prof. Müller*. It is plain, from direct *experiment*, that each and all of those portions of the reflex arc which governs the contraction of the iris, is endowed with the excito-motor property. The tubercula belong to the spinal, not to the cerebral, system; and such was the opinion of Prof. Flourens, formed from experiment alone, many years ago†, and stated in a manner replete with the deepest interest:—

* Baly's Müller, ed. 2; vol. i.; p. 755; 759; compare p. 768; 826.

† Op. cit. Pref. p. xxiii—xxv.

167. "De la délimitation même des propriétés de ces parties, établies par mes expériences, il suit que la moelle épinière finit à l'origine des nerfs de la huitième paire; que la moelle allongée s'etend de cette origine au tubercules bijumeaux ou quadrijumeaux; que ces tubercules sont tout-à-fait distincts, quant à leur manière d'agir, des lobes cérébraux et du cervelet."

168. Prof. Flourens' experiments, however, do not establish an *arc* of action, being limited to the irritation or the removal of the tubercula.

169. Mr. Mayo's experiments fail in establishing such an *arc*, by omitting its central or connecting part, the tubercula. He consequently concludes, "that in the habitual variations of the pupil, an impression is conveyed to the *brain* along the optic nerve, which is followed by an affection of the third pair, causing the pupil to contract or dilate."

170. Prof. Müller agrees with Mr. Mayo, observing, "Mr. Mayo's experiments on the nerves of the eye, with reference to the motions of the iris, proved that the phenomenon must be produced through the medium of the *brain**."

171. I need scarcely advert to the phenomenon of the excited closure of the eye-lids; excited through the trifacial, it is effected through the reflex excito-motor action of the medulla oblongata, and the facial nerve. The anatomy of this action is displayed in the following *Table*:—

ANATOMY OF THE CLOSURE OF THE EYE-LID.

I. *The Excitor.*	II. *The Centre.*	III. *The Motor.*
The palpebral branch of the Trifacial.	*The Medulla Oblongata.*	*The Orbicular branch of the Facial.*

* Handbuch; by Dr. Baly; p. 755.

172. With the view which occupies us at this moment, I may beg my reader's attention to a paragraph in my Second Memoir (§ 125). It relates to a passage, full of interest, by M. Magendie, and another by Mr. Mayo. It shows what 'groping in the dark' existed with our first physiologists, at the period so little remote as that at which those passages were written :—

173. M. Magendie observes*, "Le mouvement, nommé *clignement*, dépend en partie du nerf facial, et en partie du nerf de la cinquième paire. Il cesse quand le nerf facial est coupé ; il cesse ou ne se montre que très-rarement, et seulement par l'effet d'un rayon directe de lumière solaire, quand le nerf de la cinquième paire est divisé. La perte du mouvement des paupières par la section, ou la paralysie du nerf facial, s'entend facilement, puisque ce nerf envoie des filets au muscle orbiculaire. *Il est beaucoup plus difficile de comprendre comment la section de la cinquième paire arrête le clignement, car ce nerf, presque entièrement destiné a la sensibilité, n'envoie aucune branche aux muscles qui font mouvoir les paupières.*" Mr. Mayo observes†, "The muscle which closes the eye-lids is called the orbicularis palpebrarum ; it is disposed for some breadth beneath the skin of the eye-lids in concentric fasciculi. *This muscle is supplied by the fifth nerve*, and by the portio dura of the seventh, and is paralyzed by the division of the latter. The fifth nerve and the seventh rise together ; the fifth imparts sensibility to the eye, to the eye-lids, and eye-lashes ; and the least irritation of these parts calls into action the orbicularis palpebrarum, which receives its stimulus through the portio dura of the seventh."—"The *consent* between the fifth and the seventh nerve," &c.‡ These two eminent physiologists are at variance in their anatomy, but obviously attach importance to the question of the distribution of the fifth to the orbicularis itself

* Précis de Physiologie ; Paris, 1833, t. i. p. 51.

† Outlines of Physiology, 3rd ed. p. 307. ‡ Op. cit. p. 308.

—so excluding the very idea of a *reflex* action: the former confesses the difficulty of explanation of the phenomenon; the latter attaches importance to the identity of *origin*, referring the phenomenon to some "consent" between the two nerves,—an opinion controverted with perfect success by Dr. Alison* and Prof. Müller†. Neither Mr. Mayo nor M. Magendie appears to see that the act involves a reflex, excito-motor agency, carried on through the medium of the true medulla,—a fact which is proved by experiments in which the fifth pair of nerves, the medulla, and the seventh pair of nerves, are respectively divided. The central and connecting link between the two nerves, as between the excitor and motor nerves of the true spinal system generally, and in *all* acts of ingestion and egestion, of the orifices and sphincters, is overlooked.

174. In regard to the closure of the larynx, the facts are similar. A reflex excito-motor arc is formed by a branch of the superior laryngeal nerve, by the medulla oblongata, and by the inferior laryngeal nerve. Thus, Dr. J. Reid observes‡:—"that when any irritation is applied to the mucous membrane of the larynx, in a healthy state, this does not excite the contraction of the muscles which move the arytenoid cartilages by acting *directly* upon these through the mucous membrane, but that this contraction takes place by a *reflex action*, in the performance of which the superior laryngeal is the *sensitive* (?), and the inferior laryngeal is the *motor* nerve."

175. I may illustrate this subject by adducing the following *Table* of the

* Trans. of the Med.-Chir. Society of Edinb. vol. ii, p. 165; and Outlines of Physiology, 1833, p. 269.

† Handbuch der Physiologie, ed. 1. p. 689.

‡ Ed. Med. and Surg. Journ. vol. xlix. p. 146.

ANATOMY OF THE CLOSURE OF THE LARYNX.

I. *The Excitor.*	II. *The Centre.*	III. *The Motor.*
The Superior Laryngeal.	*The Medulla oblongata.*	*The Inferior Laryngeal or Recurrent.*

176. The anatomy of deglutition is illustrated in the subjoined *Table*:—

ANATOMY OF THE ACT OF DEGLUTITION.

I. *The Excitors and Motors which* close *the Larynx.*

II.

I. *The Excitors*	II. *The Centre of Deglutition.*	III. *The Motors*
1. *The Glosso-Pharyngeal?*	*The Medulla oblongata.*	1. 1. *The Pharyngeal—*
2. 1. *The Pharyngeal—*		2. *The Œsophageal—*
2. *The Œsophageal—*		3. *The Cardiac—branches of the Pneumogastric.*
3. *The Cardiac—branches of the Pneumogastric.*		

III. *The Immediate Excitors of Irritability in the Œsophagus.*

IV. *The Excitors and Motors which* open *the Cardia.*

177. The rest of these reflex excito-motor arcs are enumerated in the general Table of the Anatomy of the True Spinal Marrow. This Table enumerates, whilst Plate II depicts, what I view as the anatomy of the true spinal, or excito-motor, system—an anatomy as far higher than the transcendental tracings of mere fibres, in my estimation, as it is more immediately and largely useful in its applications to physiology. I have just quoted most interesting paragraphs both from Prof. Flourens and

Prof. J. Reid: the former *did not* see that a reflex excito-motor arc was established by his experiments, because such views of the subject were unknown, undiscovered; the latter was enabled to do so, because my investigations on this subject had afforded him the clue which alone could conduct him through the labyrinth!

178. To Prof. J. Reid we are indebted for the proof that œsophageal deglutition is, as well as that part of this function which is performed in the pharynx, a reflex excito-motor act; and that it is performed through the medium of incident and reflex branches of the pneumogastric nerve, with their connecting link, the medulla oblongata*. I had previously supposed that the œsophageal part of deglutition was an effect of irritability. This exclusive view is corrected by Prof. J. Reid. Singularly enough, it is substituted by one, which, being equally exclusive, is equally erroneous. I shall adduce facts, in a subsequent part of this Memoir, which will prove that œsophageal deglutition is a function of a mixed or compound nature, excited partly in a *reflex* manner, and partly by the direct and *immediate* stimulus of the muscular fibres of the œsophagus.

179. I may be allowed to observe, in this place, that the pharynx, the function of which is purely excito-motor, is supplied by distinct muscles, whilst the œsophagus has, rather, a muscular coat. It should be observed too, that, whilst the pharynx and œsophagus are excited to contraction, the cardia, so firmly closed generally that not the pressure of the whole weight of the body will overcome its power (witness the sailor lying with his stomach across the yard-arm), is *opened*. This fact, with the singular positive relaxation of the sphincter ani during the effort to expel the fæces, presents a subject for investigation of deep interest.

180. But of all the reflex excito-motor arcs, of all the anatomy of

* Op. cit. p. 154.

the reflex functions and its central organ, the true spinal marrow, that part which relates to *Respiration*, is the most signally important. I have therefore devoted an entire plate (Plate III) to this vital subject. Legallois proved that the medulla oblongata was essential to respiration; his discovery was confirmed by Prof. Flourens. They have erroneously concluded that that which was *essential* was also the *primum mobile.* Sir Charles Bell has arranged certain muscular nerves as *respiratory.* The second and third steps towards an explanation of the acts of respiration were taken. The first remained undetected. I have distinctly proved, by experiments, that certain incident nerves are the excitors, the *prima mobilia* of respiration; and that the whole form *reflex arcs* not previously suspected even.

181. The incident, excitor nerves of inspiration are—1, the trifacial; 2, the pneumogastric; and 3, the spinal. Through the medium of the first and third, the first inspiration is excited; and, through the medium of the second, the subsequent acts of inspiration, during the rest of life. But I am anticipating a subject which must be discussed at large in a subsequent section.

182. It has been observed that, whilst the superior laryngeal nerve is the excitor, and the inferior the motor, in the excited closure of the larynx, the excitor and the motor nerves of the œsophagus are contained within the same sheath—are equally branches of the œsophageals. An anatomy, similar to this latter, prevails at the lower part of the animal frame, where the excitor and motor nerves of the sphincters, of the rectum, the bladder, the uterus, are of this character. In one case, the excitor and the motor nerves are distinct, however, in this region, viz. that of the excited action of the expulsion of the semen, the excitor originating in the glans penis, the motor being distributed to the detrusor seminis.

183. There is one consideration in the anatomy of the lower

part of the true spinal system, of great practical importance—the long and oblique course of the nerves to and from the lowest portions of the spinal marrow. I frequently see mistakes, made by the most eminent physicians, in regard to this point. In paraplegia, I observe that the issues or setons have been applied over the seat of numbness. Knowing that the nerves of these parts have the connection with the spinal marrow very much higher than their origin or distribution in the integuments, it is plain that the remedy ought to be applied not over the seat of numbness, but much higher.

184. I have already noticed the fact that irritation of the posterior columns of the spinal marrow and posterior roots of the spinal nerves, will induce reflex muscular actions. Without the discovery of the system of these actions, such a fact must have been a great obstacle to the proof of the *Lex Belliana*, an obstacle which this discovery alone has removed. To this discovery, then, that law or doctrine is certainly deeply indebted. Without it, how could it be asserted that the anterior roots alone of the spinal nerves are devoted to muscular motion, when it is observed that irritation of the posterior roots also induce a similar effect?

185. I do not, however, agree with Prof. J. Reid in the following observation:—"Dr. M. Hall, availing himself of the late discoveries, by which it has been shewn that the nervous filaments which transmit impressions to the central organ of the nervous system, are distinct from those which convey the motive influence back to the muscles, has extended and more fully illustrated this view of the independence of these sympathetic movements upon sensation, and has formed it into a kind of corps de doctrine*."

186. I have examined the course of the operations of my own mind

* Op. cit. p. 156.

in this investigation, and can affirm that no such idea as that stated by Prof. J. Reid has guided me, either in its commencement or during its progress. The reflex function is established by facts, and these would exist whether we were ignorant of the *Lex Belliana* or not. It is a question of experiment,—of physiology first, and then of anatomy.

187. I have already stated what the Lex Belliana owes to the establishment of the system of incident and reflex nerves, in reference to facts which must have appeared opposed to it, had they not been explained. I beg to refer the scientific reader to the works of Prof. Müller, of Dr. van Deen, of M. Longet, &c. for ample discussion of this question. Prof. Müller perceived all the difficulty of the case. Dr. van Deen has commented on the question at length*. M. Longet has also frequently adverted to the subject†. The late Sir Charles Bell himself, whom it is impossible to mention without the honour due to a name destined to live as long as physiological science shall endure, never seems to have perceived the different relations of this argument.

188. It will be readily perceived, from what has been said, in what point of light I regard the paragraph, or rather the disquisition, of Dr. van Deen‡, in which he states that the doctrine of Sir Charles Bell and that of the reflex function are to be explained or demonstrated by a reciprocal aid :—" Pour moi je suis convaincu que la doctrine de Bell doit être prouvée par celle de Marshall Hall, comme la doctrine de ce dernier doit l'être par celle de Bell. *Jamais l'une de ces doctrines ne pourrait être prouvée, si l'autre n'existait pas.*"

* Traité et Découvertes sur la Möelle Épinière; p. 46.

† Anatomie et Physiologie du Système Nerveux; t. i. p. 272; &c.

‡ Op. cit. p. 52, &c.

SECTION III.—*The Physiology of the True Spinal System.*

189. It is difficult distinctly to separate the consideration of the anatomy from that of the *Physiology* of the true spinal system, so intimately united are these two questions.

190. The first physiological remark I would offer, relates to the complete distinction between the functions of the cerebral, the true spinal, and the ganglionic portions of the several nervous systems. Whilst the cerebral system places us in relation with the external world *mentally*, the true spinal *appropriates* some of its materials in the *mass*, and the ganglionic performs the same office still more intimately in regard to its *atoms*.

191. Every act of ingestion, of retention, of expulsion, or of exclusion, is a reflex act, an excito-motor act, an act of the true spinal system, performed through its incident nerves, its central organ (the true spinal marrow), and its reflex motor nerves; an act of the special power seated in this system. I have always wondered that such an extensive generalization did not excite more admiration of Nature's works.

192. If we wish, then, to know what are the special acts of the true spinal system, we have only to ask—what are the acts by means of which masses of matter are ingurgitated into and expelled from the animal œconomy?

193. These acts are found to preside over two important classes of functions,—those of the *preservation of the individual* and of the *propa-*

gation of the species. The designs of Nature in the functions of the true spinal system are, therefore, obvious.

194. These views will be made conspicuous by a careful examination of the following Table of

THE PHYSIOLOGY OF THE TRUE SPINAL SYSTEM.

I. *The Excited Actions—*

1. *Of the Iris ;—of the Eye-lids.*
2. *Of the Orifices* { 1. *The Larynx.* 2. *The Pharynx.*
3. *Of the Ingestion*
   1. *Of the Food,*
      1. *In Suction ;*
      2. *In Deglutition.*
   2. *Of the Air, or Respiration.*
   3. *Of the Semen, or Conception.*
4. *Of Exclusion.*
5. *Of the Expulsors, or of Egestion.*
   1. *Of the Fæces ;*
   2. *Of the Urine ;*
   3. *Of the Perspiration ;*
   4. *Of the Semen ;*
   5. *Of the Fœtus, or Parturition.*
6. *Of the Sphincters.*
   1. *The Cardia.*
   2. *The Valvula Coli ?*
   3. *The Sphincter Ani.*
   4. *The Sphincter Vesicæ.*

II. *The Direct Action or Influence—*

I. *In the Tone,* } *of the Muscular System.*
II. *In the Irritability,* }

195. It must appear a remarkable assertion that, before the discovery of the true spinal system, *not one* of this long list of functions was, or could be, understood! One of them, deglutition, was referred to the immediate stimulus of the food upon the sub-mucous muscular fibre; another, respiration, was considered as an act of volition by some, but more distinctly referred to the medulla oblongata as its "fons et origo," its primum mobile, by others. Not one was understood. In vain do we look in Whytt, or Monro, or Unzer, or Prochaska, or any of the innumerable authors from whom scraps have been quoted, to deprive me, if possible, of the just reward of my labours, for any *idea* even, of a reflex, excito-motor, *physiological* act, or system of acts.

196. I refer to my former writings for the physiology of excited closure of the eye-lids, of the glottis, &c. &c.; and proceed to devote a little space to the consideration of the nature of the act of deglutition, to which I have already briefly adverted, § 178. This subject has been specially treated of by Prof. J. Reid* and Prof. Volkmann†. These eminent physiologists are opposed in their view of the nature of the act of deglutition in the œsophagus. The discrepancy I believe to originate in too exclusive views of the subject. Prof. J. Reid observed that, after the division of the pneumogastric nerves above the origin of the superior laryngeals in the rabbit, the principal part of the parsley eaten by the animal remained in the œsophagus; a few leaves was all that reached the stomach.

197. Prof. Reid observes—"This arrestment of the movements of the muscular fibres of the *œsophagus* in deglutition, after section of the *pneumogastrics*, proves that this does not depend upon any diminution in the contractility of these muscular fibres, but upon a breach being made

* Edinburgh Medical and Surgical Journal, vol. xlix, p. 5.

† Archiv für Physiologie, von Dr. J. Müller, 1841, p. 348.

in the nervous circle, which, through the intervention of the *medulla oblongata*, connects the muscular with the mucous coat. We, therefore, conclude that the muscular contractions of the œsophagus are not called into action by the ingesta acting directly as an excitant upon the muscular fibres through the mucous membrane, but by a reflex action, part of the *œsophageal* filaments of the *par vagum* acting as motor, and others, in the manner of sensitive (!) nerves*." Yet there is no sensation!

198. Prof. Volkmann concludes, from experiments made on the calf, in which the pneumogastric nerves were divided, and on the frog, in which the brain and spinal marrow were destroyed, that the deglutory movements of the œsophagus do not depend on the pneumogastric nerves†.

199. The fact is, I believe, judging from my own experiments, that the action of the œsophagus in deglutition is of a double or mixed character,—prompt under the influence of the pneumogastric nerves, and of a slower character under the immediate influence of the peristaltic action of its muscular fibres. These views are supported by the following experiments:

200. The pneumogastric nerves were laid bare in a rabbit, and a considerable portion was removed; a little cabbage was then given. Deglutition seemed to be perfect at first; soon, however, uneasiness and a sort of cough was induced, a little of the cabbage with mucus being expelled. The rabbit was killed by a blow on the back of the neck.

201. On examination, the stomach was found replete with bran, &c. and the œsophagus with the green cabbage; not a particle of the latter had reached the stomach, but a little was found in the larynx and trachea. The peristaltic movements of the œsophagus were very marked, and expelled the cabbage through the lower extremity when this was cut.

* Op. cit. p. 154. † Op. cit. p. 359.

202. A *comparative* experiment was tried. Two rabbits were taken and a portion of each pneumogastric nerve was removed in *one*. A very little cabbage was then given to both. In twenty minutes they were killed. In the rabbit in which the nerves were entire, the cabbage was found entirely in the stomach, the œsophagus being quite empty. In the other, a very little of the cabbage had passed into the stomach, whilst the œsophagus contained it from beginning to end.

203. The action of the œsophagus under the influence of the pneumogastric nerves is, like that of the pharynx, rapid and energetic. Its action, after the nerves are divided, is slow and peristaltic, like that of the intestine. The latter is obvious in the œsophagus separated entirely from the animal, and of sufficient power slowly to expel its contents.

204. But the extraordinary fact is the positive relaxation of the cardia, both in deglutition and in vomiting; a fact which is not, however, without its parallel in the animal œconomy. Thus the larynx is dilated in the act of inspiration, and the sphincter ani in the act of expulsion of the fæces. The pores of the skin are relaxed under the influence of certain emotions.

205. The dilatation of the cardia in deglutition and vomiting is, like the simultaneous closure of the larynx, a reflex action; only it is peculiar, and highly worthy of consideration.

206. The important subject of inspiration is reserved for consideration in a distinct section.

207. On passing the eye over the plate (*Plate* II), it will be observed that the liver and kidney are introduced into it. It may be difficult to ascertain whether there be any excito-motor action connected with the hepatic ducts or the ureter. But it is certain that calculus in either of these canals may induce excito-motor phenomena; vomiting is a marked example of this; so also is that peculiar and unexplained symptom, *rigor*.

I need scarcely add that much remains to be done in this investigation.

208. It is remarkable that the medulla oblongata should be the central organ of the reflex arcs in so many physiological acts. The lowest part of the medulla spinalis occupies a somewhat analagous rank in reference to the reflex acts, the organs of which are seated at the lower part of the animal frame, especially the acts of which the object is the continuation of the species.

209. The act of seminal emission is one of the simplest, reflex excito-motory acts.

210. The acts of conception and of parturition doubtless belong to the same order.

211. The expulsion of the fœtus in the human subject is sometimes induced by local excitement. The application of a few grains of salt to the sphincter has induced the expulsion of an immature egg in the hen. I have also seen the eggs expelled from the separated abdomen of the libellula by the rough contact of external objects.

212. In connection with these latter subjects, I may observe that the next improvement in the obstetric art will, I believe, arise from the application of our knowledge of the excito-motor principle to that department of medicine. Remedies in the cases of sterility and of lingering labour, of atonic hæmorrhagy and other forms of inertia of the uterus, will probably be found in some of the excitants of the excito-motor power.

213. It remains for me to call the attention of my reader to two forms of spinal action, which differ from those hitherto considered, in being, not reflex, but direct. These are

1. *The Tone,* } *of the Muscular System.*
2. *The Irritability,* }

214. I here beg to refer to my former Memoir (Memoir II, § 178—), and to a Memoir read before the Royal Medical and Chirurgical Society* on these two questions. It has been supposed that the tone of the muscular system is a reflex effect; but no *proof* has been adduced of this opinion. It has also been imagined that the acknowledged connection between the spinal marrow and the muscular irritability is not immediate, as I have suggested, but secondary, and the result of impaired nutrition. I have good reason for supposing, however, that both these views are correct, and that neither of them is to be adopted to the exclusion of the other. Early in hemiplegia, we have augmented irritability. *This* fact only admits of one explanation. In very chronic hemiplegia, with diminished nutrition, there is also diminution of the irritability of the muscular fibre.

215. I can now only further request my friendly reader to examine *Plate* II, and compare it with the Table of the Physiology of the True Spinal System, at leisure and with earnestness. He will, I am convinced, do so, as I have so often done, with much gratification. The drawing itself is admirable, and I cannot express my obligation to its designer in too strong terms. The grouping of so many phenomena *of the same Class*, hitherto unexplained and unconnected with or by any common principle of action, will also afford him much pleasure.

* See its Transactions, vol. xxii, p. 191.

Section IV.—*The Pathology of the True Spinal System.*

216. With one exception, every instance of *physiological* action of the true spinal system is *reflex*, induced through the medium of incident nerves, the spinal centre, and reflex motor nerves. The *Pathology* of the true spinal system may be regarded as nearly equally divided between *reflex* and *centric* morbid actions. I think both these generalizations of extreme interest and importance.

217. The *reflex* morbid actions may be exaggerated forms of physiological acts, though more frequently they are abnormal forms of action of the muscles devoted to such acts, excited through the usual channels, the usual incident nerves. But there is, doubtless, a class of morbid reflex actions excited through the agency of incident nerves, not usual channels of reflex physiological acts. Thus, irritation of the dura mater, the pleura, the peritoneum, &c. in experiments on animals from which the brain had been removed, induces muscular actions. What relation this fact may have to physiology I cannot perceive; it may have an influence on the condition, or tone, of the general muscular system; but it is plain that such irritation may be caused by diseases within the cavities, and lead to a new form of spasmodic disease not hitherto recognized. I have briefly noticed this subject in a Memoir read before the Royal

Medical and Chirurgical Society* ; and Dr. Burrows has adverted to it in his able lectures delivered before the Royal College of Physicians†.

218. The *centric* morbid actions arise from any source of irritation of the true spinal centre, as a morbid condition of the circulation, excess or defect, a morbid condition of the blood itself, as in asphyxia, poisoning, &c., the irritation of an inflamed arachnoid, of effusion, of a tumor, of exostosis of the spinal canal, &c. &c.

219. I must here request my reader's attention to *Plates* III and IV, the former of which portrays the contrast between *Asthma* and *Asphyxia ;* the former a reflex, excited morbid condition ; the latter, phenomena of *centric* origin, arising from the circulation of venous blood in the true medulla ; and between the similar *incident* mode of action in tetanus and the *centric*, in hydrophobia. In the same plates are depicted the phenomenon of *Vomiting ;* and in *Plate* IV, those of that most interesting malady, the *Crowing Inspiration*, &c. in infants and children.

220. These figures present the *types* of the principal diseases of the true spinal system, and must be most carefully studied. I proceed to describe each more particularly.

221. That *Asthma* (Fig. 1) consists in excited reflex morbid actions, is obvious, from its most common exciting causes : a few grains of the powder of ipecacuanha diffused in the atmosphere ; indigestible substances taken into the stomach ; effete matters retained in the intestine ; all these, with various other physical conditions, of the atmosphere especially, frequently prove the immediate exciting causes of the paroxysm of asthma, which consists, apparently, in a morbidly contracted condition of the smallest ramifications of the bronchial tubes, probably the result of a

* Vol. xviv. p. 122. † See the Medical Gazette, vol. xxxii, p. 290.

morbid, reflex action—a conjecture, however, to be hereafter illustrated by experiment.

222. In addition to this contracted condition of the minute bronchial tubes, we observe sudden acts of inspiration, and prolonged and laborious acts of expiration, probably its immediate consequences.

223. If, with this state of the respiratory functions in asthma, we compare that observed in *Asphyxia*, the contrast is most interesting: instead of excited *reflex* actions, we observe phenomena induced by a morbid stimulus applied to the *centre* of the true spinal system itself, viz. venous blood circulating in its blood vessels, and probably more or less arrested in them.

224. In the first stage of asphyxia, there is an open state of the mouth, with frequent respiration or panting; in the second, sudden gaspings, with inspirations followed by laboured expiration, at certain rather distant intervals, and with various convulsive movements.

225. *Similar* effects are induced by extreme loss of blood; and hence, apparently spontaneously, in the separated head of the kitten, the turtle, &c.

226. Similar effects are also observed, in the separated head of the kitten and other young animals, on irritating the divided surface of the medulla. This fact has been observed by Legallois:—"Si, lors mêmes que les bâillements ont fini depuis quelque temps, on touche le moignon de la moelle qui tient à la tête, on en produit un; ce qu'on peut répéter plusieurs fois*." The same fact is observed in the separated head of the turtle.

227. To the subject of asphyxia I shall return in a subsequent section of this Memoir.

* "Expériences," &c. p. 154.

228. In Fig. 3 are portrayed the singular combination of phenomena in *Vomiting*. Vomiting itself is sometimes of *centric*, sometimes of *reflex* origin. Some of the remedies, termed emetic, act in the former manner, whether taken into the stomach or injected into the veins; the loss of blood, the motion of a ship, a carriage, a swing, and a blow, also act primarily upon the central organ of the system. Irritation of the fauces, on the contrary, certain irritations of the stomach and of the intestine, and certain conditions of the uterus, act through the medium of incident nerves.

229. My present object is only to lay down the principles and modes of action in these cases of morbid affection, in a manner which cannot be doubted. I therefore pass on, at once, to the other interesting objects portrayed in this Plate.

230. *Tetanus* and *Hydrophobia* have, I imagine, always been associated by physiologists as diseases of the same nature. The former, however, is indubitably of a reflex character; the latter is indubitably of centric origin.

231. These views are all admirably set forth in Mr. Simpson's drawings, in which the reflex character is marked by the insertion of the incident nerves; whilst the centric is denoted by the insertion of the heart, the central organ of the circulation, the means by which the poison or cause of the malady is carried to that of the nervous system.

232. In Plate IV, we have beautifully portrayed the *Croup-like Convulsion* observed in children. The incident nerves proceeding from the gums, from the stomach, and from the intestines, denote the several *sources* of this malady; the condition of the hand and foot, the larynx, and the diaphragm and other muscles of inspiration—the gall-duct and ureter, and the sphincter of the rectum and the bladder—denote the affection of these parts of the system, through the medium of the

medulla oblongata, and the medulla spinalis, and the reflex nerves. Lastly, the brain is added, to call the attention of the student to the fact of congestion of this organ as the *effect* of general convulsion.

233. The pathology of the nervous system has never been thus *mapped*, as it were, before. The figures which have just been described may be considered as but the *type* of other diseases besides that to which they more immediately refer. They may, for instance, be taken as representing that form of *Epilepsy* which is not centric in its origin, and that form of puerperal convulsion which arises from the condition of the uterus itself. With this view, for the nerves denoting *dental* irritation, should be substitued those connected with the *uterine* organs.

234. Asterisks might also be added to denote the action of disease, tumors, &c. in inducing irritation of the medulla oblongata, and consequent convulsion, either immediately, as in the case of tumors, or, more remotely, by counter-pressure, as in the case of inflammation of the cerebral substance, or by reflex action from irritation of the membranes.

235. To such figures might also be added the heart, as denoting that form of convulsion which arises from exhaustion, as hæmorrhagy, and various cases of poisoned blood, as asphyxia, primary and secondary, intoxication, &c.

236. In further illustration of the pathology of the nervous system, I beg to refer my readers to a series of Memoirs, read before the Medical and Chirurgical Society*, and a little volume published rather more than a year ago†.

237. I shall conclude these brief remarks by adducing the following Table of

* See the Trans. of the Royal Med. and Chirurg. Society, vol. xxii. p. 191; xxiii, p. 121, 170; xxiv, p. 83.

† The Gulstonian Lectures, for 1842.

THE PATHOLOGY OF THE TRUE SPINAL SYSTEM.

I. *Diseases of the Incident Nerves.*

I. 1. *Dental* 2. *Gastric* 3. *Intestinal* } *Irritation in Infants.* {
1. *The Crowing Inspiration.*
2. *Strabismus, Spasm of the Fingers and Toes; Strangury; Tenesmus; &c.*
3. *Convulsion.*
4. *Paralysis?*

II. 1. *Gastric* 2. *Intestinal* 3. *Uterine* } *Irritation in Adults.* {
I. *Hysteria.*
II. *Asthma.*
III. *Vomiting; Hiccup; &c.*
IV. *Epilepsy.*
V. *Puerperal Convulsion; &c.*

III. *Traumatic Tetanus; &c.*

IV. *Disease of the Internal Tissues; see* § 217.

II. *Diseases of the Spinal Marrow itself.*

I. *Inflammation and other Diseases.*

II. *Diseases of the Vertebræ and Membranes.*

III. *Counter-pressure, &c. in Diseases within the Cranium.*

IV. *Centric Epilepsy, Tetanus, &c.*

V. *Convulsions from Loss of Blood.*

III. *Diseases arising from the impact of Poisoned Blood on the Spinal Marrow.*

I. *Asphyxia.*

II. *Hydrophobia.*

IV. *Diseases of the Reflex or Motor Nerves.*

I. *Spasm.* II. *Paralysis.*

1. *Spasmodic Tic.*
2. *Torticollis.*
3. *Contracted Limbs; &c.*

Section V.—*The Therapeutics of the True Spinal System.*

238. The remedies or the poisons which act through the medium of the true spinal system are, principally, certain *physical* agents applied to the expansion of the incident nerves. Of these agents, *heat* and *cold* hold the first rank; but to these may be added certain mechanical influences, and, in the case of corrosive poison, the physical changes induced in some of the tissues.

239. On the influence of *temperature* as a therapeutic agent, my readers may consult two most interesting papers by Mr. Simpson and Mr. Barlow, in the Lancet for 1842 and 1843.

240. The most important of all our remedies in congenital asphyxia is the sudden and forcible impression of cold water on the face and general surface. The quantity of the water should not be great, but it should be applied suddenly and with force. The temperature should not be lowered; on the contrary, the dashing of the cold water should be alternated with a warm bath, succeeded by warm flannels. These too may be applied briskly and suddenly.

241. The efficacy of the remedy is in proportion to the degree, the suddenness, the energy, of the *alternation.*

242. Continued cold depresses the energies of life; continued warmth augments them. But it is the sudden impression arising from the brisk

alternation of the cold and heat, which proves the most efficacious excitor of the respiratory function, on which recovery depends.

243. Other excitements of the surface should also be applied. In our experiments on asphyxia in kittens, we uniformly found that to pinch the tail, the feet, the ears, or the general integument, with the forceps, did not excite other reflex actions only, but acts of inspiration! We must imitate these facts. The face and the general surface should be rubbed roughly, irritated by a knitting needle, struck smartly with the open fingers.

244. The nostril and the anus are most excitable parts. Irritants must, therefore, be applied to these parts from time to time.

245. These means become more effectual after the lapse of an interval of repose; during such an interval, which obviously must not be too long, the infant may be placed in a warm bath, and be afterwards rubbed with warm flannels. The sudden dashing of cold water will then especially be doubly efficacious.

246. These plans of resuscitation should not only be long continued, but they should be continued long after the apparent institution or restoration of respiration,—with the object of preventing a relapse into *Secondary Asphyxia.* Perseverance is not less necessary in this case than in that of poisoning from opium. The blood is still poisoned, and a slight comparative failure in the respiration, as from sleep, may add to the dose of poison, and prove fatal.

247. My friend Mr. H. Smith has made a most important remark: *after* the partial establishment of respiration, therefore *after* inflation of the lungs, secondary asphyxia may prove fatal, and the life of a supposed criminal mother may be placed in fearful jeopardy, even by the medical evidence!

248. Next to the remedies which have been noticed, the exposure of the face especially to a current of cold air will prove most important;

and even after the infant is restored to animation and cloathed, its *face* should be freely exposed in a cool atmosphere. The fan may also prove of great assistance ; the sudden gusts induced by it are especially useful.

249. It is not in asphyxia only that these measures are important; in nausea and vomiting, in faintishness and syncope, in various sudden seizures, as in the convulsive diseases both of children and adults, they are equally useful. The cold breeze is the best remedy against sea-sickness, and extremely useful in asthma; the dashing of cold water on the face is the most efficacious remedy in syncope.

250. In one case, my friend Dr. Heming kept off the convulsive attack in an infant for a very long time, by watching the premonitory symptoms, and sprinkling cold water on the face or surface. It will be remembered that Dr. Denman did the same thing in a case of puerperal convulsion. The larynx is opened, inspiration excited, and the fit prevented.

251. The efficacy of the alternate application of the douche of ice-cold water, and of warm water or flannel, in uterine hæmorrhagy, is a fact of the most interesting kind. That inertia of the uterus in general, that certain forms of menorrhagia, of leucorrhœa, of sterility, of miscarriage, may be remedied by the cold water douche, opportunely applied, is most probable. It is probable, too, that the same remedy may be useful in lingering labour attended by inertia of the uterine and the general system.

252. I remember to have witnessed a bucket of cold water dashed upon the posterior parts of a mare, immediately after her removal from the stallion. Whether this treatment possesses the efficacy in making the animal 'hold,' as imagined by the grooms, I know not; but certainly the opinion that it does so is very prevalent.

253. It is a well-known fact that the bladder and intestine have been relieved under the influence of the cold water douche, enema, or bath.

254. A similar effect I have noticed induced in horses or cattle driven through a river, and in the elephant at the Zoological Gardens led into its bath. School boys have experienced the same thing; and such an effect forms a considerable part of the boasting of the hydropathists relative to their mode of treating disease.

255. It is probable that a considerable part of the *bracing* effect of the sea-breeze and of sea-bathing arises from the improved condition of the excito-motor function and power generally; and that the local application of cold water may, in like manner, induce local beneficial effects. Of the latter kind is the beneficial influence of the enema of cold water in prolapsus, &c. of the intestine. To be effectual, the water so used should be of the temperature of 42° of Fahr. It acts on the usual principle of cold, in inducing an effectual relief of the intestine at the moment, and in inducing tone of the part, with great amelioration of the malady generally.

256. I have hitherto spoken of the effect of the sudden impression of *cold*, under circumstances of a maintained condition of the temperature. There is a subject never yet investigated. It is, the sudden impression of *heat*, within the due limits of such a remedial means. The use of a bath of 104° Fahr. induces the same disposition to sob, as that of a cold bath. It might, therefore, prove an important remedy in certain cases of asphyxia, and especially in the case of drowning.

257. There is another view of the therapeutics of the excito-motor system, which ought to be taken. Every one has observed the terrible spasm induced in the tetanic and the hydrophobic patient by every kind of excitement, even the most slight. Every experimentalist has observed the same thing in cases in which the excito-motor principle has been exalted. One important consideration in the treatment of tetanus and

hydrophobia, is that of *entirely* securing the patient against every kind of excitement! With this object, he should be inclosed within a double series of curtains, of which one should surround the other at the distance of several feet. A uniform mild or warm temperature should be maintained. No movement of the atmosphere, no jar or shake of the patient's bed, or of the floor, or of the door, or furniture, should be allowed. No unnecessary visits should be permitted; no incautious word should be uttered. *Every excitant should*, in a word, *be most carefully avoided!*

258. By taking these precautions, we should at least save the patient much torture, and we should ensure to our remedies *all* their efficacy. We have only to read the "Mémoires" of Larrey, to be impressed with the extreme injury sustained by many of his patients from the impossibility of adopting such a rigid mode of excluding the exciting or aggravating causes of tetanus.

ON THE

TRUE SPINAL MARROW, &c.

PART II.

SECTION I.—*On the Acts of Respiration.*

259. As the idea of a reflex, excito-motor, physiological act, did not exist before the date of my various publications, so, least of all, was it previously suspected, or has it been even subsequently admitted, that the normal *Acts of Respiration* are *all* of that character. That they are so however, is, I believe, proved beyond a doubt by new experiments; and I think I may surely regard the establishment of this fact as one of great importance in physiology;—in a word, as *the Law of the acts of respiration.*

260. The acts of respiration must be divided into *two* orders: 1, those which, like the *first* inspiration, arise from excitement of the trifacial and spinal nerves, which have their origin in the integuments of the face and general surface; 2, those which arise from irritation of the incident portions of the pneumogastric nerves, arising from the fine mucous tissue of the pulmonary air cells.

261. The impressibility or excitability of the trifacial and spinal nerves has scarcely been appreciated by physiologists. They are greater in proportion as they are observed sooner after the birth of the animal, and gradually decline with the advancement and duration of extra-uterine life.

262. If, in a kitten, within the first nine or ten days after birth, we remove the cerebrum, divide the pneumogastric nerves, and open the trachea, the respirations gradually fall in number, until they become repeated but three or four times in the minute. If now, during the intervals between the respirations, we direct a stream of air forcibly upon the animal, or irritate the nostril, the anus, the tail, the foot, or, in a word, any part of the surface, or jar the table, an act of inspiration is immediately excited out of the usual course of these acts.

263. This phenomenon is constant. It is the more marked, the younger the animal. In a kitten within ten days from birth, it continues for an hour or two. It is still observed in kittens of three, four, or five weeks old; but, at a later period, the experiment is very apt to fail. Much, too, depends on the degree of loss of blood which has been sustained during the removal of the cerebrum.

264. In favourable circumstances, the slightest breath of air, the slightest motion, &c. induces an immediate inspiration.

265. The same phenomena are observed in cases of partial asphyxia, induced by retaining the animal, for a certain time, in a limited portion of atmospheric air. When removed and laid upon the table, acts of inspiration may be excited by any of the means which I have mentioned. A current of air induces an act of inspiration only. Irritants, applied to the general surface, induce common reflex movements, together with the act of inspiration.

166. Such are the proofs of the influence of the trifacial and spinal

nerves in exciting acts of inspiration. The proof of the influence of the pneumogastric, in exciting the same facts, is afforded by removing the cerebrum, and then dividing, first one, and then the second, of these nerves; the number of the acts of inspiration, *before* and *after* each of these steps in the experiments, gives us the measure of the influence of each organ as they are successively removed. In one experiment, the respirations were very frequent before the removal of the cerebrum, about forty after its removal, about ten after the division of one pneumogastric, and three after the division of the second. Acts of inspiration were still excited, in the manner already described, by directing a current of air upon the general surface, or applying any other form of irritation.

267. Having thus demonstrated the influence of the trifacial and spinal, and the pneumogastric, nerves, in inducing the acts of inspiration, I must beg my reader's attention to some extracts from Prof. Cruveilhier, Prof. Flourens, Prof. Volkmann, and M. Longet.

268. From Prof. Cruveilhier, I extract the detail of an experiment:—"Je mis un chien dans l'état comateux, par l'injection d'un peu d'alcohol dans la cavité de l'arachnöide; je pus alors enlever la voûte du crâne, enlever le cerveau et les obes du cervelet, sans faire mourir l'animal;"—"la section des nerfs pneumo-gastriques, à leur origine, a produit de suite la mort. Pas un seul mouvement respiratoire n'a suivi cette section*."

269. It is plain, from this experiment, that respiration may be continued after the removal of the cerebrum. It is plain, from a multitude of other experiments, that the same function may be continued after the division of the pneumogastric nerves. But if M. Cruveilhier's experiment be correct, it is equally plain, that the acts of respiration cease on the performance of *both* these operations. Accepting this experiment at the

* Anatomie Pathologique; iiie. Livraison, p. 5.

hands of M. Cruveilhier, who had offered no explanation of its nature, I concluded that, respiration being a *mixed* function, partly voluntary from the cerebrum, partly excited through the pneumogastric, its acts might be repeated, however modified, after the abstraction of *either* of these influences, though it might cease on the abstraction of *both*; that it remained purely voluntary after the division of the pneumogastric nerves alone, and purely excited after the removal of the cerebrum alone; but that it could be neither, and must consequently cease entirely on the removal of the influence of both: in fine, that it then resembled the experiment in which the medulla oblongata is itself divided at the junction of the pneumogastrics.

270. It *must*, however, have been obvious that I spoke in the most general terms; and that I, who had so often mentioned, and even reduced to the form of *Table*, the trifacial and the spinal, with the pneumogastric nerves, as excitors of inspiration, could not forget the influence of the former. For example, in my second Memoir, p. 76, § 126, I observe:—"I have ascertained that, not the medulla oblongata, but the pneumogastric nerve, is the primum mobile, as its excitor, in ordinary respiration, and the fifth and spinal nerves, as its excitors, in certain extraordinary circumstances." I may conclude this preliminary notice of the subject by adducing the following *Table* of the *Respiratory Nerves*, extracted from the same work. It consists of the *excitors* of respiration, in addition to the Respiratory system of Sir Charles Bell:

THE SYSTEM OF RESPIRATORY NERVES.

I. *The Excitors.*	II. *The Medulla Oblongata.*	III. *The Motors.*
1. *The Trifacial,*		1. *The Intercostal.*
2. *The Pneumogastric,*		2. *The Diaphragmatic.*
3. *The Spinal, Nerves.*		3. *The Lower Spinal, &c.*

271. Again, p. 88, §162, I have said:—"This remark leads me to observe that the pneumogastric is not the *only* excitor of inspiration. Inspiration is equally excited through the fifth and spinal nerves; a fact proved by the familiar phenomena induced by dashing cold water upon the extremities of the former in the face, and by impressing the latter by a similar influence on descending into the cold bath. The first act of inspiration in the newly-born infant is probably excited through the medium of the fifth and spinal nerves conjointly, by the contact of the atmosphere, as the first acts of expulsion of the fæces and urine are excited during the similar contact of the atmosphere with the extremities of the spinal nerves." And at p. 90, § 169, I again throw my view into the form of *Table*, and observe:—"It appears, from these various facts, that the acts of inspiration are excited acts, and excited through the medium of several excitor nerves. These may be arranged thus:—

1. *The Trifacial.*
2. *The Pneumogastric.*
3. *The Spinal.*"

272. In one word, my remarks referred exclusively to the experiment of M. Cruveilhier. Every time I have written on the cause of the first inspiration, on the influence of the cold bath in adult age, &c. &c. paragraph after paragraph, and table after table, prove that I was deeply impressed with the importance of the trifacial and spinal nerves as primary, auxiliary, or residuary excitors of respiration.

273. The reader will, after this observation, readily comprehend the following experiments and remarks of Prof. Flourens:—

274. "M. Marshall Hall dit, dans ses beaux *Mémoires sur le Système Nerveux*, que, si l'on opère tout à la fois sur un animal, le retranchement du *cerveau*, et la section des *nerfs pneumo-gastriques*, la respiration est sur-le-champ abolie.

275. J'ai enlevé, sur un pigeon, les deux lobes cérébraux (le cerveau proprement dit), et j'ai coupé l'un des nerfs pneumo-gastriques. L'animal survivait et respirait très bien encore le lendemain de l'operation, époque où il a été employé à d'autres expériences.

276. " J'ai enlevé les deux lobes cérébraux et coupé les deux nerfs pneumo-gastriques, sur un lapin. L'aminal n'a plus respiré qu'avec effort ; il restait couché sur le côté ; mais enfin il a survécu (et par conséquent respiré encore) pendant plus d'une demi-heure.

277. " La même opération a été pratiquée sur un chien. Il a survécu pendant plus d'un quart d'heure.

278. " J'ai enlevé les deux lobes cérébraux et coupé les deux nerfs pneumo-gastriques sur un pigeon.

379. " Immédiatement après l'opération, l'animal, qui avait le jabot plein, a été pris de vomissements."

280. " Du reste, il respirait et vivait très bien.

281. " Le lendemain de l'opération il vivait encore.

282. " J'enlevai le cervelet, et je coupai les deux nerfs pneumo-gastriques, sur un autre pigeon.

283. " L'animal vivait et respirait très bien trois heures après l'opération, époque où il fut employé à d'autres expériences.

284. " Les deux tubercules bijumeaux furent enlevés, et les deux nerfs pneumo-gastriques coupés, sur un troisième pigeon.

285. " L'animal survivait et respirait très bien trois heures après l'opération, époque où il était employé à d'autres recherches.

286. " Enfin, sur un quatrième pigeon, je commençai par couper les deux nerfs pneumo-gastriques ; après quoi, j'enlevai d'abord les deux lobes cérébraux, puis le cervelet, puis les tubercules bijumeaux ; la moelle allongée restait donc seule, mais restait entière.

287. " L'animal survivait, et par conséquent respirait encore, plus de deux heures après l'opération.

288. " Je répétai cette expérience, sur un lapin. L'animal survécut à l'opération pendant à peu près vingt-deux minutes: sa respiration n'était plus, à la vérité, continué; mais elle se reproduisait de temps en temps, et surtout quand on irritait l'animal*."

289. " Ainsi: 1°. l'abolition de la respiration n'est pas immédiate et brusque dans les expériences qu'on vient de voir, comme elle l'est dans l'expérience de la section transversale de la moelle allongée à l'origine de la huitième paire.

290. 2°. " Le *mouvement respiratoire* survit au retranchement combiné des nerfs pneumo-gastriques et des lobes cérébraux; des nerfs pneumo-gastriques et du cervelet; des nerfs pneumo-gastriques et des tubercules bijumeaux; il survit au retranchement de toutes ces parties (les lobes cérébraux, le cervelet, les tubercules bijumeaux), combinés avec la section des nerfs pneumo-gastriques: ce mouvement ne dépend, donc, *essentiellement* (et il ne s'agit ici que du principe primordial, *essentiel*, de ce mouvement), ni d'aucune de ces parties prise séparément, ni de toutes prises ensemble.

291. " 3°. Avec la section, au contraire, de la moelle allongée vers l'origine de la huitième paire, et avec cette seule, à l'exclusion de toute autre lésion, tout *mouvement respiratoire* cesse sur-le-champ. C'est donc dans cette moelle, et dans cette moelle seule, que réside le principe *essentiel* et primordial de ce mouvement†."

292. It must be remembered that division of the medulla excludes the influence of the trifacial as well as that of the pneumogastric nerves, and that it also destroys the central part of all the reflex arcs of respiration.

293. It is obvious that, in the young quadruped, the acts of respira-

* Système Nerveux, p. 204—206.

† Opus cit. p. 207.

tion are excited in the manner described in § 166. But in the bird, another circumstance is called into operation. The spinal nerves are, in fact, in the bird-tribes, a sort of *analogue of the pneumogastric:* the respiration being *general* or *diffused* over the system, as in insects; the spinal nerves being distributed to these diffused air cells; and being excitors of respiration, it is obvious that, in the bird-tribes, respiration *must* continue to be excited through these channels, after both the removal of the cerebrum and the division of the pneumogastrics. To suppose otherwise, would be to suppose that, in this special case, where it is most required, the excito-motor power, the power of exciting inspiration, is withdrawn from these analogues, the pneumogastric nerves.

294. In the insect, as in the bird-tribes, the respiration, with its excitors, is general and diffused over the body, the spinal nerves becoming, from their distribution to the tracheæ, or air cells, analogous to the pneumogastric. But, in the insect tribes, there is an additional structure still, each distinct segment possessing *a ganglion analogous*, in its relation to respiration, *to the medulla oblongata.* If the libellula be divided into several portions, as represented in Plate III, each distinct portion,—head, thorax, and sections of the abdomen,—continues to move, as in respiration, in the entire animal; a fact which involves an important discovery, suggesting a new field of investigation in the anatomy and physiology of insects.

295. In the *young* quadruped, respiration *is* excited through the medium of the spinal nerves, after the removal of the brain, and the division of the spinal marrow, by excitants applied to the external surface. In the bird, a similar effect is induced through the medium of the spinal nerves distributed over the air cells, diffused amongst the general tissues, just as a similar effect is induced through the medium of the pneumogastric, distributed to the air cells of the lungs.

296. These facts do not in the least invalidate the experiment of Prof. Cruveilhier, which presents the usual result when performed upon adult animals. Far less do they sanction the conclusion of Prof. Flourens.

297. I repeat that my conclusions referred to the experiment of M. Cruveilhier only; the influence of the trifacial and spinal being, on that occasion, kept out of the question. But I, least of all, can be considered as ignorant of that influence, after the published remarks, quoted §§ 270, 271.

298. I need scarcely now reply to the observations of Prof. Volkmann:—"Hall's theory is improbable in this respect: were the vagus the *exclusive* medium of the involuntary respiratory movements, &c. &c.*"

299. As I never imagined the pneumogastric nerve to be the "*exclusive*" excitor of respiration, as stated by Prof. Volkmann, so I never was of opinion that it is the "*essential*" excitor of respiration, according to M. Longet†. And, in spite of the observations of the latter physiologist (vol. i. p. 308), I am persuaded that volition *is* the regulator of the movements of respiration. This is perceived in the effect of *sleep*, or of *intense attention*. The respiration becomes slow, irregular, and audible, by the abstraction of all volition. I am also satisfied, by experiment, that there is a greater truth, and a more important truth, than M. Longet himself imagines, in the paragraph which also occurs at p. 308 of his useful work, beginning with "C'est à peine," &c. See § 262, and compare § 265.

300. The observations of Prof. Volkmann are of a different character; his conclusions different; but equally opposed, I believe, to the truth.

301. Prof. Volkmann observes—"The respiratory movements appear, indeed, to be reflex in their nature, but in the following way: the excitant

* Müller's Archiv, 1841, p. 336.

† Anatomie et Physiologie du Système Nerveux; Paris; 1842.

is carbonic acid, but not that become free in the air-passages, but that still remaining in the blood; and the place of irritation is each part of the body, not merely the lungs; lastly, the excitor nerve is each centripetal nerve which proceeds to the medulla oblongata; not exclusively the vagus*."

302. Now there are two points expressed or implied in this paragraph upon which I must remark: the first is, that the acts of respiration, though excited, are not excited by means of external stimuli applied to the trifacial or spinal nerve, and of evolved carbonic acid in the air-cells of the lungs; but by this acid still circulating in the blood, and brought into contact with nervous fibres diffused amongst the tissues; the second, that there are acts of respiration without exposure to external stimuli, as, within the detached ovum, or under water.

303. In regard to the first of these, I may observe that the phenomenon of acts of inspiration excited by external stimuli, is an indubitable experimental fact; and that this phenomenon takes place when the contact of venous blood and its carbonic acid with the tissues will produce no such effect:

304. If we remove the cerebrum and divide the pneumogastric nerves in a young kitten, the number of the acts of respiration may be reduced to four in a minute, in spite of the circulation of venous blood; but, by directing a stream of air on the animal, or irritating various parts of the general surface, we may excite twenty or thirty acts of respiration within that space of time. Compare § 288.

305. In regard to the second point mentioned by Prof. Volkmann, I have to observe that the specific effect of the circulation of *venous* blood, or its carbonic acid, is totally different from an act of inspiration; it consists, in fact, of *gasping*, followed indeed by inspiration, but also by spas-

* Müller's Archiv, 1841, p. 342.

modic action, denoted by a sustained state of inspiration, by forcible expiration, and by convulsive actions of various kinds; in a word, by the phenomena which I shall have to describe immediately, as peculiar to asphyxia.

306. It has also been shewn, § § 119—121, that the circulation of *arterial* blood is the essential condition of respiration.

307. Further, if Prof. Volkmann's view were correct, we ought to have augmented respiration in that condition of animals termed hibernation, in which the blood is indeed venous, but the acts of respiration rare.

308. The further consideration of this subject is reserved, however, for the next section. I conclude in this, as the result of a multitude of experimental facts, that

The Excitors of Inspiration are

1. *The Trifacial,*
2. *The Pneumogastric, and* } *Nerves;*
3. *The Spinal,*

and that there is no argument, certainly no fact, to induce us to suppose that the medulla oblongata is the *primum mobile* of the acts of inspiration.

Section II.—*On the Respiratory Movements in Asphyxia.*

309. As it was not imagined, before the publication of my investigations on the subject, that all the acts of respiration are reflex and excited, excited through the medium of appropriate incident nerves, so it could not be understood that the essential difference between these acts and the respiratory movements observed in *Asphyxia*, consists precisely in the difference between *reflex* and *centric* modes of action; yet such is *the Law of the respiratory movements in Asphyxia.*

310. I have already alluded to this subject in the last section. I now proceed to develope my views more particularly.

311. If, in a young kitten, we remove the cerebrum, divide the pneumogastric nerves, and open the trachea, we may perceive a slow but rhythmic respiration, without any abnormal appearance. If we now close the trachea, all is changed: the animal opens its mouth wide, or *gasps*, makes a strong effort at inspiration and *expiration*, is drawn together, and variously convulsed. If we remove the obstruction to the entrance of air into the trachea, the same slow but rhythmic respiration is established as before. If we again close the trachea, we have again the special phenomena of *Asphyxia.*

312. This alternation of normal acts of inspiration and abnormal actions of the respiratory muscles, may be observed many times in the

same animal. The difference between the circulation of arterial and of venous blood,—the difference between the acts of respiration, and the respiratory movements in asphyxia, is most obvious.

313. If we immerse a young kitten in water of 98° of Fahr. we first observe voluntary movements, being attempts to escape; then there is a transitory calm; then there are, from time to time, gaspings, attempts at inspiration, followed by forcible expirations, with the escape of bubbles of gas, with mucus, and perhaps blood, from the lungs, and sometimes of milk from the stomach, and convulsive flexure of the trunk of the animal.

314. Such are the special phenomena of asphyxia. Such are the true effects of the circulation of venous blood within the medulla oblongata. Extreme loss of blood produces similar gaspings, which are also observed in the separated head. So that there can be no doubt that a morbid condition of the central organ of the system, itself, is the cause of this series of phenomena.

315. But whilst this central organ is in this morbid condition, other irritations will excite similar morbid forms of the respiratory movements; such as irritation of the nostrils, of the general surface, &c.; such as, in a word, would, in a normal condition of this organ, excite normal acts of inspiration.

316. No one can duly consider these experiments, and fail to understand the following remarks of Prof. Volkmann, or to perceive that, in reality, the learned Professor is mistaking the abnormal respiratory movements peculiar to asphyxia, for physiological acts of true respiration.

317. "When I opened the eggs of fowls or of snakes, containing a sufficiently developed embryo, under water, movements were manifested which resembled gaspings for breath, forcible stretching of the neck, apparently painful turnings and twistings of the body (but not convulsions), in short, motions bearing the closest resemblance to the respiratory in

asphyxia. These motions, which, in my investigations of the development of the snake, I frequently had occasion to observe, do not indeed take place immediately after the opening of the egg, but after some time; they also continue to increase in vigour for a certain time, and in the interval the fine red colour of the blood changes to a purple. The observations of my former assistant, Dr. Schneider, are still more important. The latter cut out of the body of a hare, recently shot, some perfectly mature young ones. At first, the little animals lay in the transparent membranes, as if dead; they then began to move, and their motions so much resembled those in asphyxia, that he quickly opened the ovum, in order to save the young creatures. The same gentleman repeatedly observed the birth of puppies. These are brought into the world uninjured, and lie at first quite motionless. After some time, movements commence, and the mother usually awaits this moment to bite off the ovum*."

318. "Leclard shewed that the mature embryos breathe in the liquor amnii. Not only were the respiratory movements plainly perceived by the eye, but matter which was injected by a small orifice into the amnion was found in the lungs. Leclard inferred, from these observations, that the fœtus breathes, but the liquor amnii†, instead of air."

319. To these extracts I must add a third:—"I removed the brain of a kitten, with the exception of the medulla oblongata, cut the vagus on both sides, and extirpated the lungs, preserving the diaphragmatic nerves. The breathing, however, continued for forty minutes after the removal of the brain! Did I not fear to engage in theoretical views (hereafter to be developed), I should say that the inspirations increase in vigour and frequency soon after the removal of the lungs. In every case, the movements were very energetic, the diaphragm was powerfully contracted, the thorax

* Müller, Archiv, 1841, p. 340–341. † Ibid. p. 340.

strongly elevated. I repeated the experiment on several puppies, with exactly similar results. In reality, these experiments contain nothing unexpected; for it has long been known that a separated head will continue to breathe for a certain time; in young rabbits, I witnessed it for seventeen minutes after decapitation‡."

320. It is the important distinction, which it is the object of this section to unfold, between the acts of inspiration and the movements in asphyxia, which affords the *Key* to the discovery of the real nature of both. As long as these are confounded; as long as it is not perceived that these two orders of movements are intrinsically different, one being a *reflex*, the other a *centric*, action; as long as we attempt to illustrate one of these by the other, as identical in its nature; so long must the progress of investigation and discovery be arrested.

321. *Some* of the results of Prof. Flourens' experiments (see § 288) are the results of asphyxia, and centric in their origin; but then they are also, not physiological, but pathological. Nothing can be more important to the future investigation of this matter than this distinction. Prof. J. Reid, Prof. Volkmann, and indeed all who have hitherto entered into the inquiry, have failed for want of perceiving this important difference.

322. I here draw my Memoir to a close. My object has been to state *principles*—to unfold an important *Theory*. I reserve many details for another occasion. The subject of Asphyxia especially I propose to bring before the Medical and Chirurgical Society during the next session. I shall then give a series of experiments, made with the view of ascertaining, more clearly than before, the intimate nature of this affection, the real powers of our remedies, and the precise limits of our hope, or hopelessness, in regard to recovery.

‡ Ibid. p. 337–338.

APPENDIX.

323. In this Appendix, I propose to insert several paragraphs omitted in their proper place.

324. The first of these relates to

Rigor.

325. Rigor seems in many instances to be a reflex action. It occurs most distinctly as an effect of irritation within the intestinal tube, the gall ducts, the ureter, the urethra. It is an effect of severe and sudden inflammation of the serous and cellular membranes and other tissues. But it is, in an especial manner, an effect of that physical lesion of the tissues, especially of the liver, which occurs in the act of suppuration.

326. The most remarkable of the facts to which I have just adverted, is that of irritation of the urethra: the introduction of the catheter or bougie induces, in some very susceptible subjects, the most severe rigor,—a rigor so severe, indeed, as to imitate that of ague.

327. The second is the valuable note of Mr. Simpson, to which I have alluded, § 239:

"Stamford, Dec. 1, 1842.

"My dear Sir,

328. "Some little time ago, I had under my care a case of puerperal convulsions, which terminated well. In the course of it, two circum-

stances illustrative of your system occurred. The patient became conscious, but was obstinate. With great difficulty I forced some liquid into the mouth, but she would not swallow; I, therefore, dashed cold water in the face, and the contents of the mouth were constantly gulped down. This novel mode of making patients swallow was repeated, I should say a dozen times, and with the same invariable effect. During the convulsions, the labour stopped. There was, as it were, a metastasis of muscular action from the apparatus of parturition, to that over the whole system. Every resource in this state of things which was employed to produce uterine pains did but aggravate the general convulsions, without acting on the uterus itself.

329. "After the lapse of many hours, however, the labour was resumed; and now the cold water, applied suddenly to the abdomen, was most effective in producing uterine contractions. After a little while, however, this lost its utility. The abdominal surface becoming cold from the repeated application, the water no longer acted as an excitant. Accordingly, warm flannels were applied to restore the temperature, and then cold water was again applied, with decided effect. This alternate application of cold and heat strikes me as being something new; it is of great value in cases of hæmorrhage from the uterus. The vital power of the patient is unable to bear the continued application of the cold; and when that ceases to do good, it must, under such circumstances, produce harm. With the alternate application of heat and cold, however, the latter valuable remedy may be used, so long as it is necessary, without fear of its utility being worn out*.

"Your's most truly,

"CHAS. SIMPSON."

"To Dr. Marshall Hall."

* See the Lancet for December 1842, p. 437.

330. The third is an account of an interesting experiment by Mr. Barlow, in the paper to which I have also referred in § 239, and with which the reader may compare § 242 :—

331. Mr. Barlow observes—" I decapitated an eel, and excited quick forcible spasmodic movements in its body, placing it in water at the temperature of 120°. They were similar to those writhings which are sometimes seen in portions of this fish when they are fried ; and which the ignorant think are the consequences of feeling and indications of suffering. I observed gaspings in the separated head, which ceased after a time ; these, I imagine, would not have been renewed, had the head been suffered to remain at rest. I now introduced my finger into the mouth, and pushed it to the posterior part of it, but failed to excite the act of deglutition, which would have followed had the excito-motory principle been vigorous, just as it occurs in the apoplectic patient, when food, unconsciously to him, is conveyed backwards to the pharynx. It struck me that I could restore the reflex actions by the use of warmth ; and, therefore, I put the head into water of about the temperature of 90°. Then there happened frequent and energetic gaspings, and the act of deglutition could be induced *by the same stimulus which was perfectly fruitless previously to the immersion.* This experiment appears to demonstrate the power of warmth as a restorative of the reflex function in a striking manner ; and here temperature operated, without doubt, through that same principle by which it excites in cases of asphyxia, empties the bladder, and contracts the uterus*."

* See the Lancet for May 13, 1843, p. 221.

EXPLANATION OF THE PLATES.

PLATE I.

The principal part of this Plate is devoted to the Demonstration of the Identity of the reflex, excito-motor power, with the *vis nervosa* of Haller; of its newly discovered modes and laws of action; and, through these, of its further Identity with the power which acts in the experiments of Redi, Whytt, &c., and in all the acts of Ingestion, of Expulsion, &c. in the animal œconomy:

Fig. 1, *a* and *b*, denote the mode of action of the *vis nervosa* of Haller, long known to physiologists;

Fig. 2 denotes the same mode of action with that in its *retrograde* course; see § § 99—101, proving the identity of the principle of action in both;

Fig. 3 adds the *incident* and *reflex* modes of action to the direct (of Haller, Prof. üller, &c.), and the retrograde, again demonstrating the identity of the principle of action in all;

Fig. 4 proves the incident action along the posterior roots of the spinal nerves, and the retrograde action along the posterior column of the spinal marrow;

Fig. 5 brings us back to the experiments of Redi, Whytt, &c.

Fig. 6 and 7 carry us forward to the physiological acts of Ingestion, Expulsion, &c.

Fig. 8 denotes the incident, reflex, downward, and upward action of the same power, especially observable in cases of pathology; see § § 96—113.

For a description of the rest of this Plate, I beg to refer my reader to § § 126—132.

The Laws of Action of the Vis Nervosa.

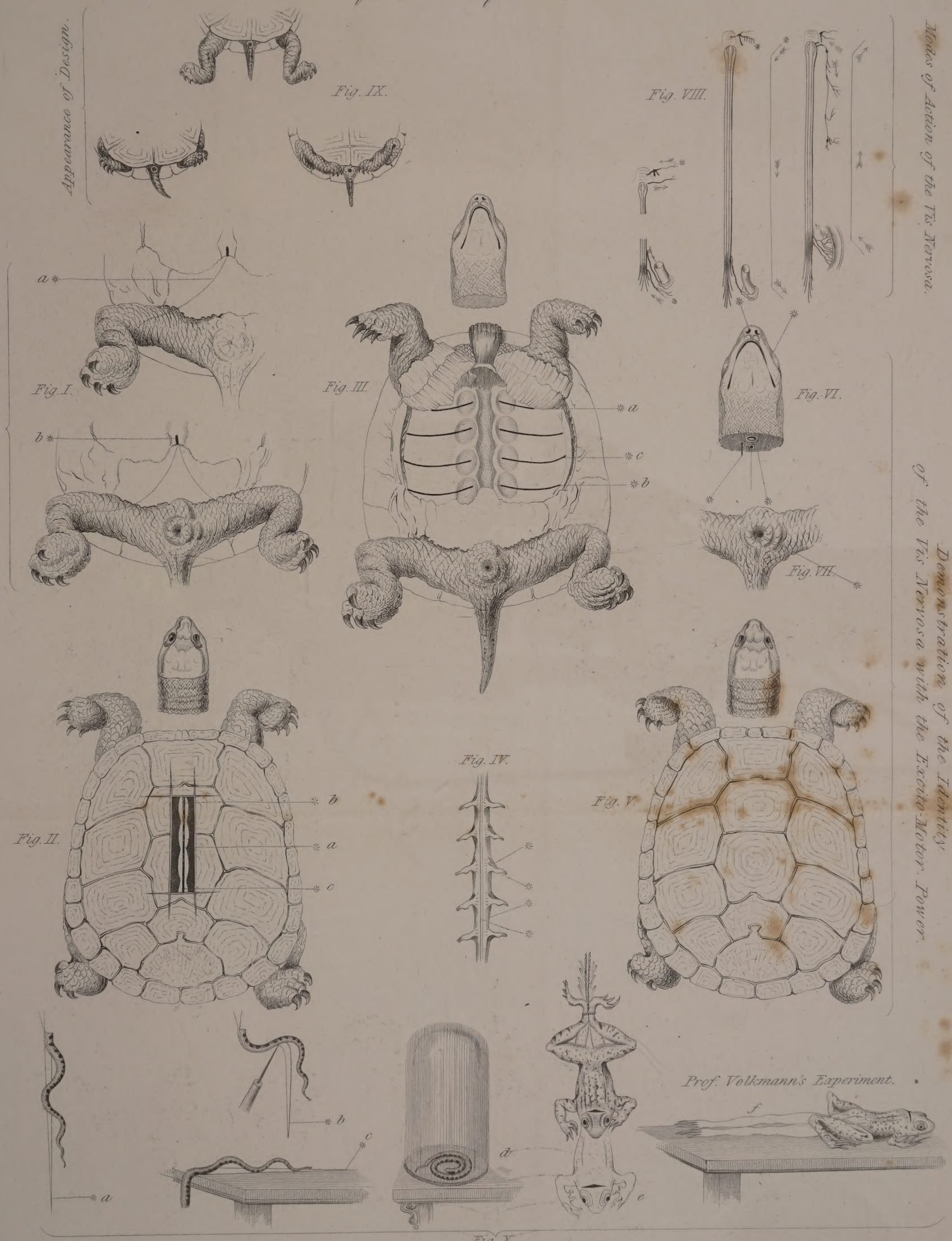


Fig. X.
Absence of Sensation and Volition.

C. Simpson, Surgeon.
Stamford, del.

J. Bull, Sculp.

London, Published by H. Baillière, Regent St. 1843.
Written & Printed by Brooker & Harrison.

PLATE II.

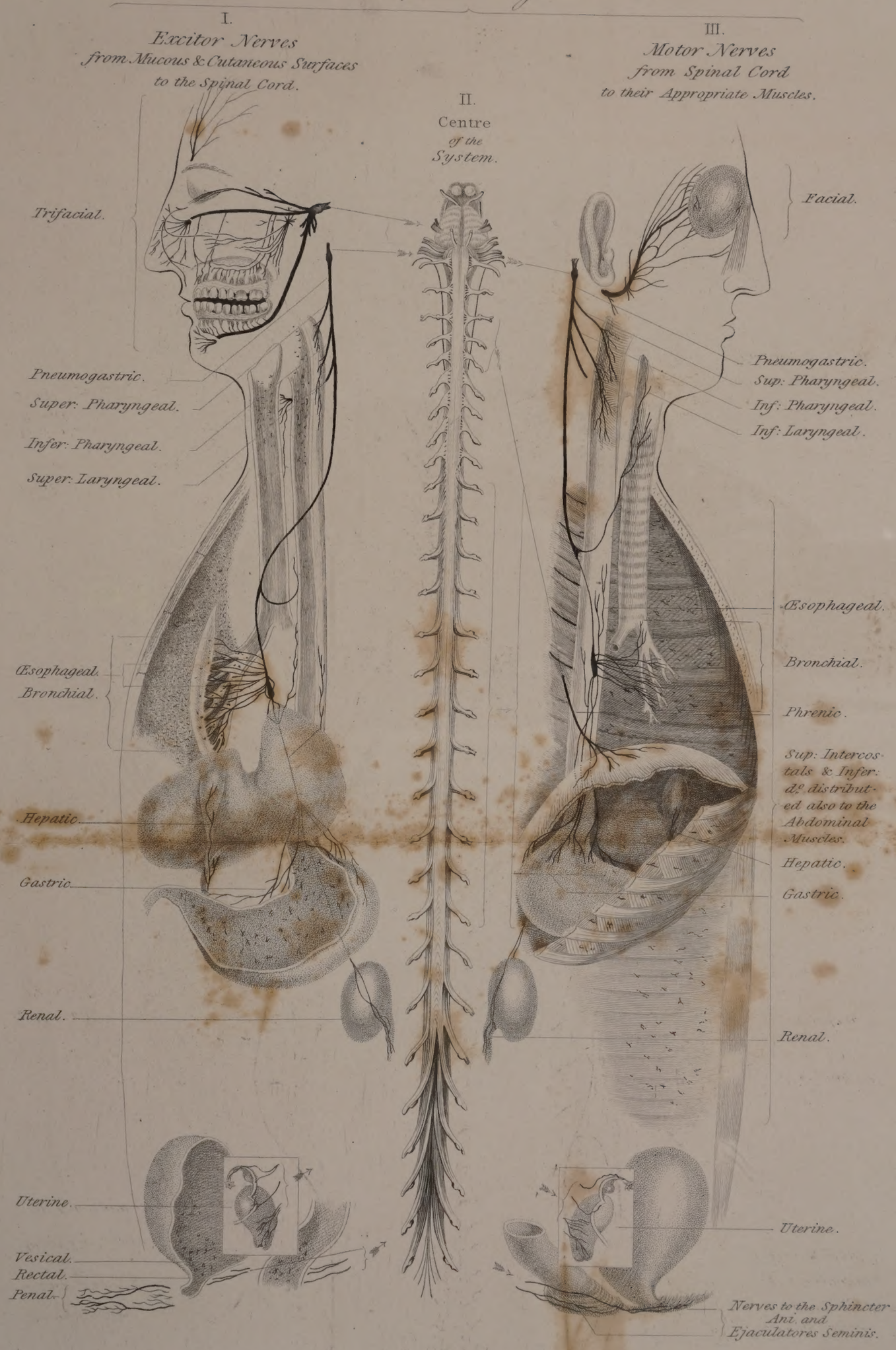
This Plate represents the True Spinal System; viz.

1. *Its Incident Nerves;*
2. *Its Spinal Centre;* and
3. *Its Reflex Nerves.*

These in their various connections constitute the *Reflex Arcs,* involved in every act of Ingestion and Egestion.

These arcs constitute *the anatomical principle or Law of the acts of Ingestion and of Egestion,* throughout the animal œconomy.

The True Spinal System.



Charles Simpson, Surgeon, Stamford, Del.

London, Published by H. Baillière, Regent St. 1843.
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J. Bull, Sculp.

PLATE III.

This Plate displays the anatomical relations of the Nerves of the Acts of Respiration; they consist of—

1. *The Incident Nerves,*
2. *The Centre, or Medulla Oblongata,* and
3. *The Reflex Nerves,*

involved in these Acts.

These again display *the anatomical Law of the Acts of Respiration.*

Fig. 2 represents the divided Libellula (see § 294), and the respiratory acts continued in each separate segment; each of which must involve, therefore, analogues of

The Medulla Oblongata.

Respiration.

IV. an Excito motory Act.

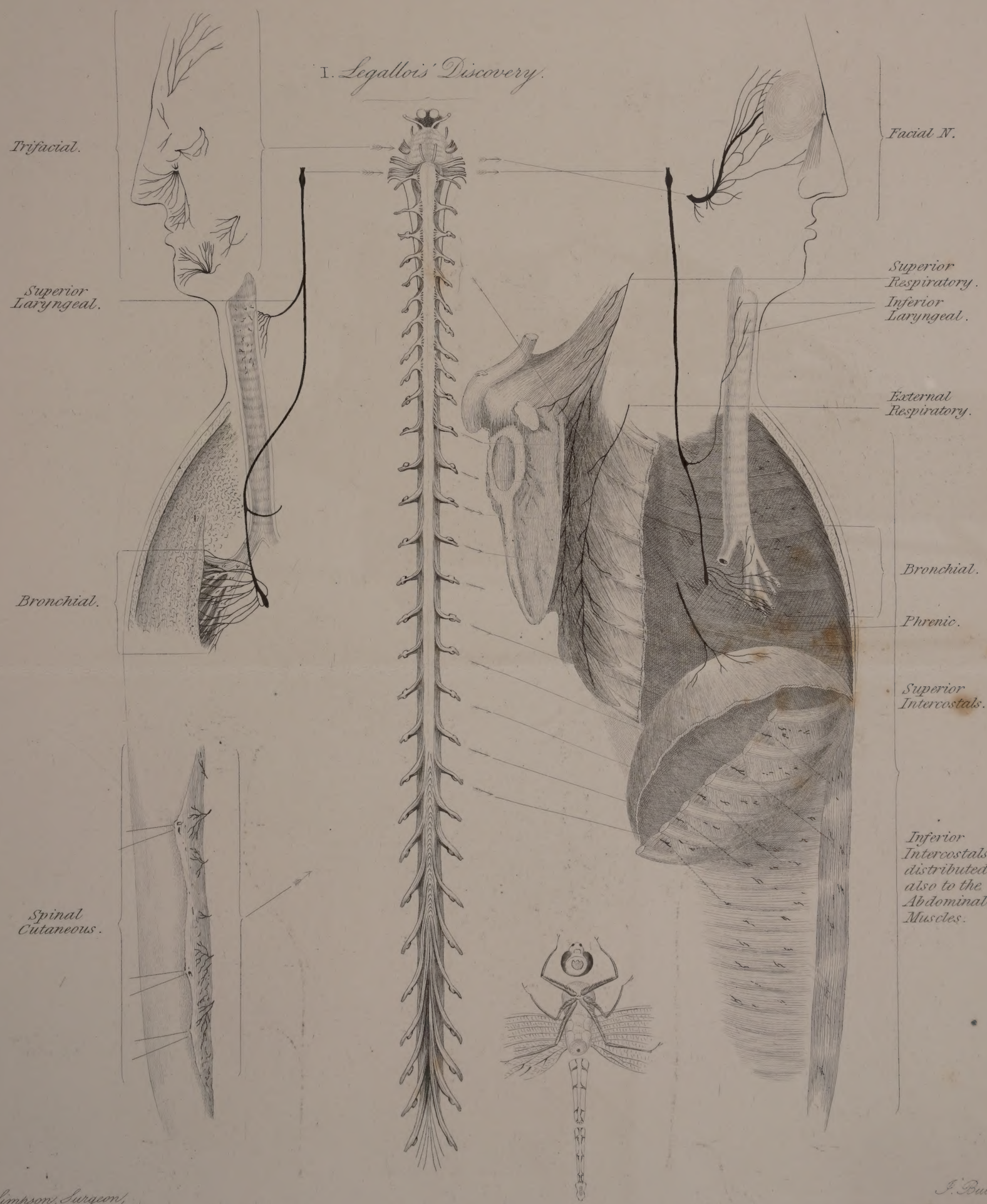
III. The Author's View.

Excitor Nerves,
from Mucous & Cutaneous Surfaces
to the Spinal Marrow.

II. Sir Chas. Bell's View.

Motor Nerves,
from the Spinal Marrow
to their Appropriate Muscles.

I. Legallois' Discovery.



Charles Simpson, Surgeon, Stamford, del.

J. Bull, Sculp.

London, Published by H. Baillière, Regent St. 1843.
Written & Printed by Crocker & Harrison

PLATE IV.

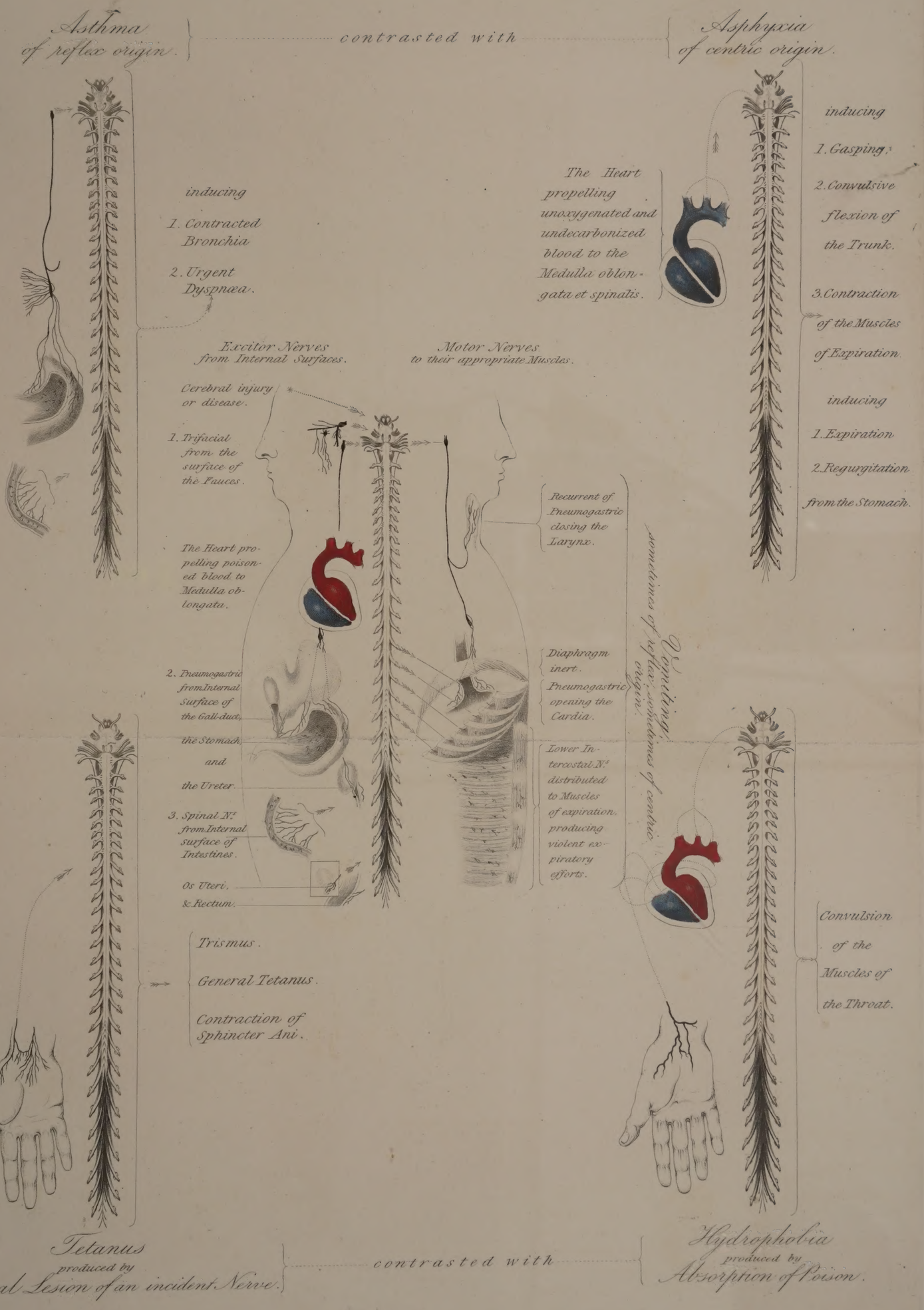
In this Plate we have portrayed the grand distinction between

The Reflex Acts of normal Respiration (Plate III), and

The Respiratory Movements of Centric origin in Asphyxia;

and the further distinction between other morbid affections

1. *Of Reflex*, and
2. *Of Centric* } *Origin*, respectively.



Charles Simpson, Surgeon, Stamford, Del.

London, Published by H. Baillière, Regent St. 1843.
Written & Printed by Brooke & Harrison.

J. Bull. Sculp.

PLATE V.

Plate V *maps* the series of

1. *Primary*, and
2. *Secondary* } affections in the

1. *Convulsions of Children ;*

and, with a little modification, in the

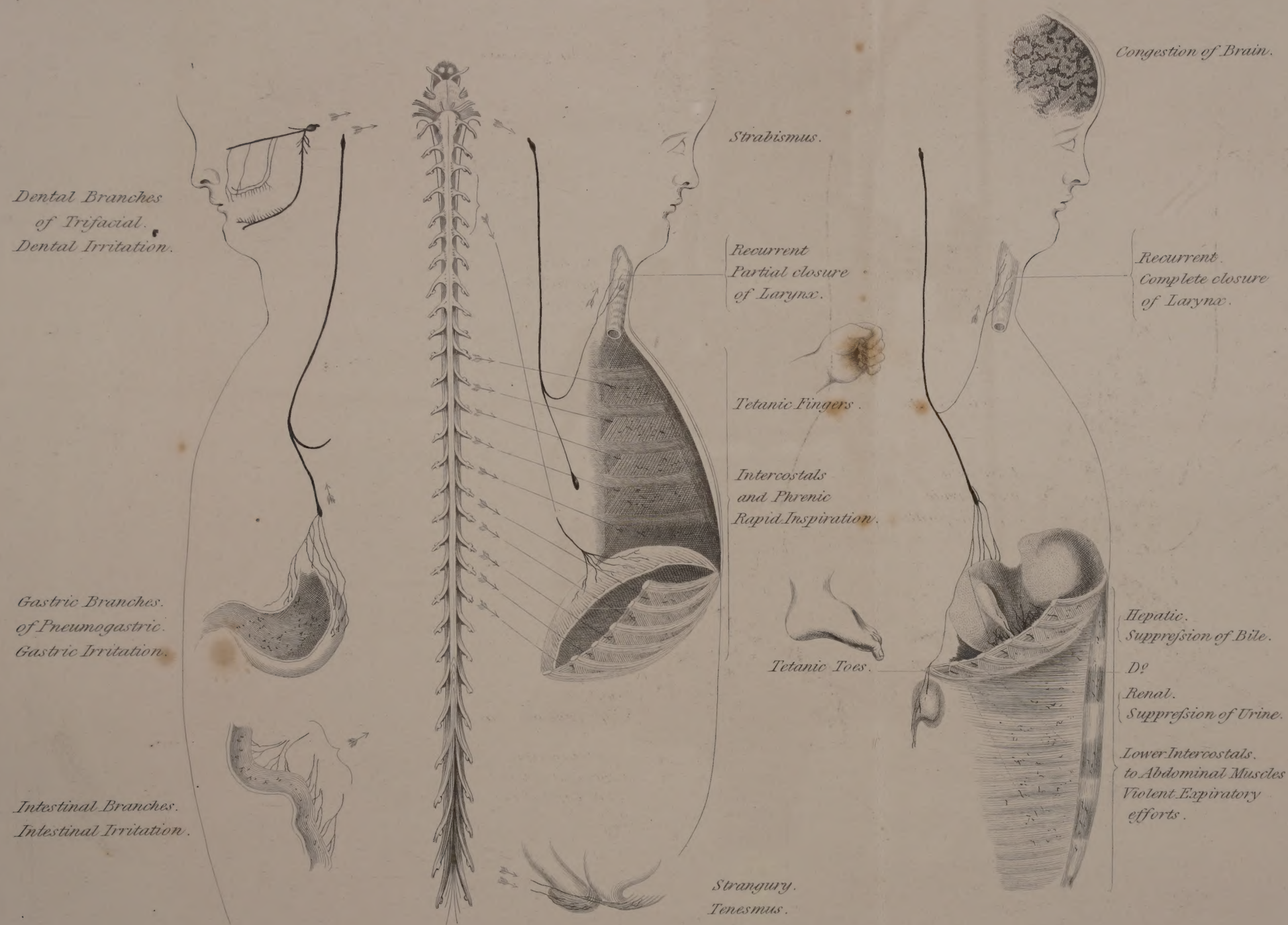
2. *Epilepsy in Adults ;*

consisting of

1. *Irritation*, with its *Incident* course ;
2. *Spasmodic Actions* of *Spinal* origin, and
3. *Cerebral* affection, their consequence.

Crowing Inspiration proceeding to Convulsions.

Excitor Nerves & Causes. Reflex Nerves & Effects.



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Recapitulation.

332. We are now in a position to review the course of events in this investigation:

333. 1. The existence of reflex actions, as mere phenomena, has been long and universally known to physiologists; a circumstance which has been admitted from the beginning. (Mem. I, § 107.)

334. 2. The dependence of these actions on the spinal marrow has also been long known; it was known to Whytt, and it has been particularly noticed by Mr. Mayo;

335. 3. But that the knowledge of these facts did not constitute or imply that of the *System* or *Theory* of the reflex actions, is proved by a singularly interesting paragraph in the able work of M. van Deen, written, as he expresses it, "dans le temps que la decouverte du mouvement de reflexion m'était encore inconnue*."

336. "Vix opus est, ut moneam, me haud assentiri Cl. J. Mullero, dicenti: 'Die Fische und Amphibien sind selbst nach dem Verluste des Gehirns und Kopfes noch einige Zeit der willkürlichen Bewegung fähig.' (Conf. Johann Müller, *Ueber die Metamorphose des Nervensystems.* Meckel's *Archiv.* 1828, p. 15.) Accuratiori enim investigatione facillime invenimus, motum illum nullo modo voluntarium esse dicendum. Secundum

* Traités et Découvertes sur la Phyisologie de la Moelle Épinière; Leide, 1841, p. 193.

hance opinionem judicantibus etiam decapitatæ muscæ volatus, actio foret habenda arbitraria. Narrat Gachet (*Ann. des Sciences Naturelles*, Mars 1833, p. 291), abscissam *Tritonis marmorati* caudam* etiam per aliquod temporis intervallum regulariter moveri. An hicce motus etiam a voluntate pendet? An etiam hujus motûs stimulus voluntas est? Omnis enim motus stimulo indiget; quinam hic stimulus sit, difficile discernitur, neutiquam tamen credo, voluntatem his in casibus stimulum esse†."

337. 4. The facts thus well known were misinterpreted: for, with the exception of Blane, they were referred to *sensation;* and, with the exception of M. van Deen, they were referred to *volition:* whilst they are, in the most comprehensive sense, independent of either; and, though connected with the spinal marrow, they were not *limited* to this organ, *exclusively* of the cerebrum and cerebellum;

338. 5. The facts were also perfectly sterile in reference to the principle of action involved in them, and to physiology. It is true that Prochaska noticed, in connection with them, one or two *very obvious pathological* phenomena; viz. sneezing, and cough; but he went no further; and he confounded with these, certain really voluntary acts, and the action of the heart, the intestines, &c. He has not noticed *one* of the extensive series of *physiological* reflex actions, which really constitute the *system.*

339. 6. The detection of the true principle of action in the reflex movements; the application of this principle and these movements to physiology; the generalization of the phenomena, both experimental and physiological, have resulted from my own persevering labours;

* It was this very fact which suggested to my view the entire *system* of reflex actions, with their application to physiology.

† De Differentia et Nexu inter Nervos; 1834.

340. 7. On the other hand, the existence of that principle of action, designated by Haller the *vis nervosa*, was also universally known;

341. 8. But *one* mode only of its influence—*the direct*—had been observed, and it had, and could have, no application to physiology;

342. 9. By a series of connected experiments, I discovered the *retrograde*, and the *incident* and *reflex* modes of action of this principle;

343. 10. I identified this principle of action with that which is operative in the *reflex actions;*

344. 11. And I was enabled, for the first time, to point out and to trace its application to physiology and to pathology,—a generalization certainly of very great extent;

345. 12. The *channels* through which this power or principle of action operates, constitutes the *Anatomy* of the system; they consist of—

1. *Incident Excitor Nerves;*
2. *The True Spinal Marrow;*
3. *Reflex Motor Nerves.*

346. 13. It is true that many authors still persist in calling the incident spinal nerves, for example, *sentient* nerves; but are they not voluntary nerves too? and would any one venture to designate them by this latter term alone and unqualified? and are they not also *excitor* and *motor* nerves, or nerves in which the *vis nervosa* acts in appropriate directions? I confidently leave this question for *time* to determine!

347. 14. Then the question presents itself—Are these different phenomena effected through the medium of *the same*, or of a *distinct*, class of *fibres?* This is a question which I leave to future investigation, merely stating my opinion, founded on analogy, to be, that for each separate function there is its peculiar structure;

348. 15. In the cerebrum, and in the nerves of special sense, we

have, positively, structures which are *in*-excitor, viz. unendowed with the *vis nervosa*, viz. the true medulla and certain nerves: whilst the spinal marrow, and the trifacial and the facial nerves, are, on the contrary, specially excitor, that is, specially endowed with *that* nervous power;

349. 16. There is one interesting fact which I have not noticed in the preceding pages: the *vis nervosa*, in the true spinal marrow, exerts a *continual centric* action on the muscles, constituting the *tone* of the muscular system, and the source of its irritability*, an influence not exerted by the muscular *nerves;*

350. 17. The *vis nervosa* in the true spinal marrow also admits of *augmentation*, as in tetanus, a second fact not observed in the mere muscular nerves, however these may be endowed with the nervous power in its normal condition, as proved by the simple experiments of irritating a muscular nerve detached from its connection with the spinal marrow;

351. 18. Nevertheless each muscular nerve does possess *within itself* the power of exciting muscular contraction on being irritated; as do also all the incident excitor nerves; these nerves are, therefore, more than *mere conductors;*

352. 19. From this property, therefore, which they indubitably possess, I have considered them, and denominated them incident excitor, and reflex motor nerves, terms which are the mere expression of the *facts;*

353. 20. Much has recently been done to illustrate the subject of the anatomy of both the voluntary and the reflex movements, especially by Prof. Müller, M. van Deen, and Dr. Stilling; but nothing can affect my view of the subject, which is, as I have stated, the simple expression of the facts; whilst all beyond is still veiled in mystery;

* I do not exclude, in this view, the influence of the circulation and nutrition.

354. 21. There is then, in the true spinal marrow, a property which does not exist in the muscular nerves,—a power of continuous action, susceptible of augmentation; but there is also a power in the incident and reflex nerves themselves;

355. 22. Without regarding this power as identical with electricity, it may be considered as *analogous* to it, and as of a *physical* character as distinguished from all that is *psychical*, a distinction not perceived by those who have most treated of this matter, as Whytt, Legallois, &c.

356. 23. I long ago observed, (Mem. II, p. 44, note), that movements were produced by stimulating the posterior, as well as the anterior roots of the spinal nerves, in the turtle and the skate; this fact would have presented an insurmountable obstacle to the proof of the *Lex Belliana*, in reference to the posterior and anterior roots of the nerves, had not the principle of the reflex actions been discovered;

357. 24. A similar remark applies to the facts connected with the posterior and anterior columns of the spinal marrow*;

358. 25. The term *reflex* expresses the *Law*, the term *excito-motor*, the *mode* of action, whilst the *vis nervosa* constitutes the *principle* of action itself, in this series of phenomena and of functions;

359. 26. The *Physiology* of the reflex actions presents the most extensive application of the principle to which I have adverted: it comprises *the whole series* of

The Acts of { *Ingestion*, *Retention*, *Egestion*, and *Exclusion*,

in the animal œconomy.

* See "Diseases of the Nervous System," p. 45, § 228.

360. 27. The *Pathology* of the system is *reflex ;* or *centric* and *direct:* it is reflex in traumatic tetanus; it is centric and direct in hydrophobia ; it is reflex in asthma, and centric in asphyxia;

361. 28. The reflex actions in the pathology of this system may originate in the nerves of the cutaneous or mucous surfaces, or in those of the internal tissues: this is a subject still requiring the most assiduous investigation ;

362. 29. The pathology comprises the *whole Class of spasmodic diseases ;*

363. 30. The *Therapeutics* of the system are, like the pathology, of reflex and of centric origin, according as the agents are *physical* in their character, or *absorbed* into the vascular system ;

364. 31. Of all the physiological acts and pathological relations of this system, *Respiration* and *Asphyxia* are the most important;

365. 32. The *Law of the Acts of Inspiration* is, like that of *all* the acts of ingestion, *reflex ;*

366. 33. The *Law of the actions of the respiratory muscles* in *Asphyxia* is *centric* and *direct ;*—a distinction of the utmost moment;

367. 34. Lastly, it is as a *whole* that I wish this system—*excito-motory*, *reflex*, and of the *vis nervosa*—to be viewed by physiologists ; this *whole* constitutes the *true-spinal* system, as distinguished from

1. The Cerebral, and
2. The Ganglionic.

Subjects of new Inquiry.

368. Much remains to be done in prosecuting the subject of these papers, as I wish to do, in their relation to the other parts of the nervous system, to the vascular system, and to the general animal œconomy; but especially in relation to the *practice of medicine.* I beg to refer my readers

to four Memoirs on the Pathology of the Nervous System, published in the Transactions of the Royal Medical and Chirurgical Society (vol. xxii, xxiii, xxiv), and to my Gulstonian Lectures delivered before the Royal College of Physicians in 1842, for specimens of this kind of investigation.

369. The seats and modes of action of volition, of emotion, of external and internal stimuli, still require new and cautious investigation:

370. A recent experiment of Dr. van Deen, and of Dr. Stilling, is, especially, full of the deepest interest: one half of the spinal marrow is divided above, and the other below, the origin of the brachial nerves, for example;—the *whole*, therefore, of this organ is divided,—yet sensation and voluntary motion remain! There is, therefore, no continuous rectilinear course of nervous fibre from the brain to the extremities!

371. A fact of deep interest has been particularly noticed by myself: emotion acts in limbs totally paralysed to volition in hemiplegia!

372. Another fact of no less moment is that of the susceptibility to *pain* in an animal deprived of cerebrum and cerebellum, the medulla oblongata being uninjured.

373. The influence of the *vis nervosa* on the internal functions; the influence of *shock*, are other subjects which require investigation.

374. The three series of the cerebral, the true-spinal, and the ganglionic symptoms, in *all* the diseases of the nervous system,—their comparative importance in the prognosis, especially, present further objects of enquiry to the practical physician.

375. But to enumerate all the topics of interest in connection with the subject of this memoir would be endless. Every case as we pass along the wards of an hospital, or visit our private patients, presents objects of new inquiry of the deepest interest. These the anatomist and the physiologist alone can comprehend, and a knowledge of the excito-motory

system has become as essential in the study of the diseases of the nervous system, as that of auscultation in those of the heart and lungs.

376. Hemiplegia, for example, limited to the cerebral system, and manifested by affections of the voluntary motions alone, is free from danger, however complete; but if dysphagia, or dyspnœa, or other affection of the excito-motor system, be added, there is proportionate danger; and if these symptoms continue, in spite of our remedies, the prognosis is fatal! still more if the ganglionic functions are implicated and there be diffused crepitous rattle, tympanitis, &c.

377. The conditions of the eye and of the eye-lid, of the tongue, of the larynx, pharynx, &c. of the bladder and rectum, in reference to the voluntary and reflex movements, and the secretions, also present objects of the deepest interest to the physician, and of vital consequence to the patient.

378. In every point of view there is much to be done. Every encouragement should be given to the diligent and devoted investigator; every obstacle, every kind of injustice, every source of disgust and of indignation, should, for the sake of science, for the honour of our institutions, be removed. The physician, who devotes himself to investigation, especially, makes a thousand sacrifices; his path requires cheering, and should not, as it need not, be unjustly obstructed or beset with thorns.

FINIS.